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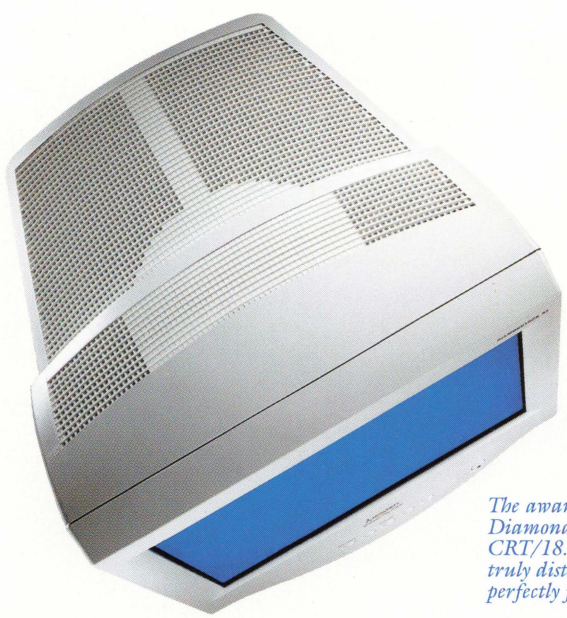

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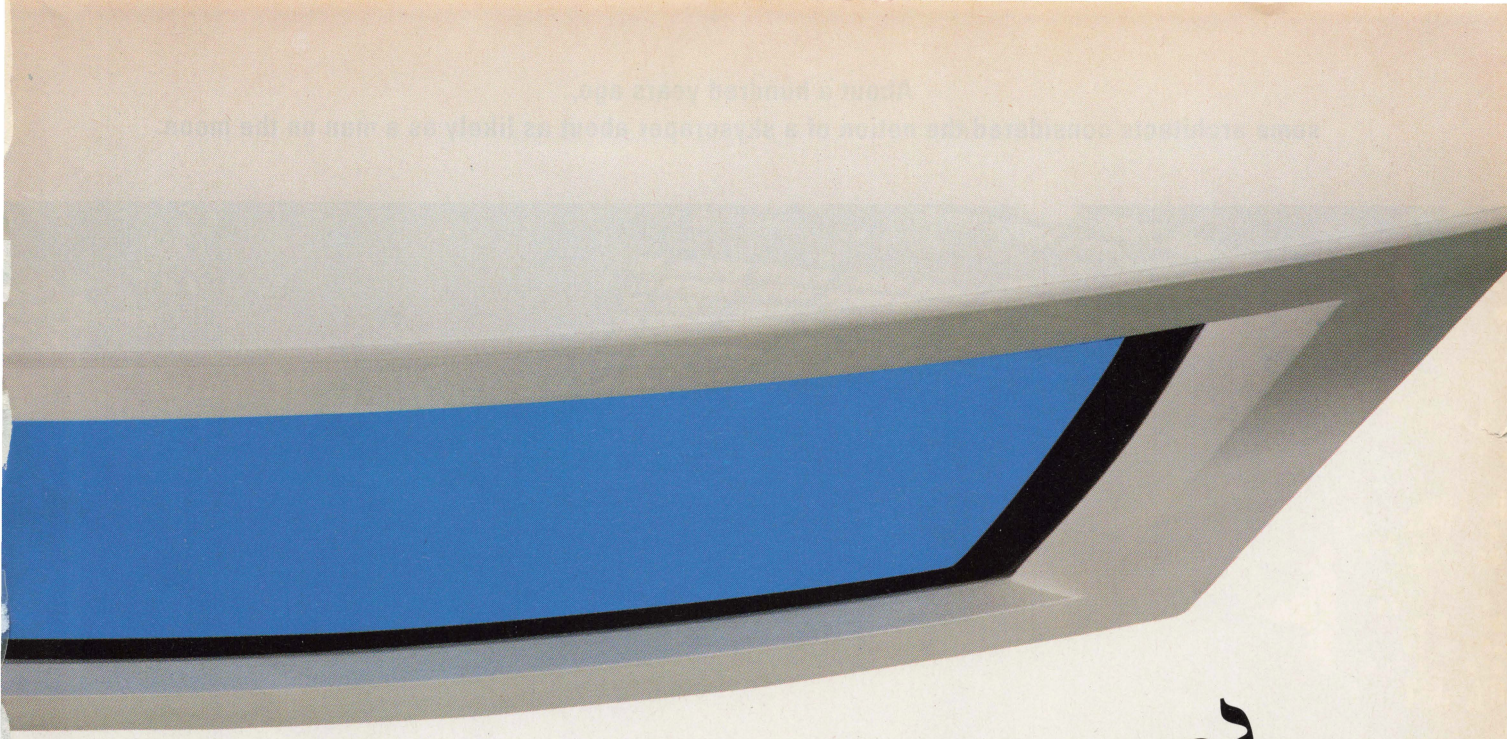

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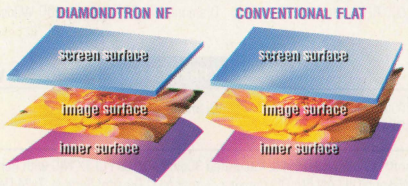

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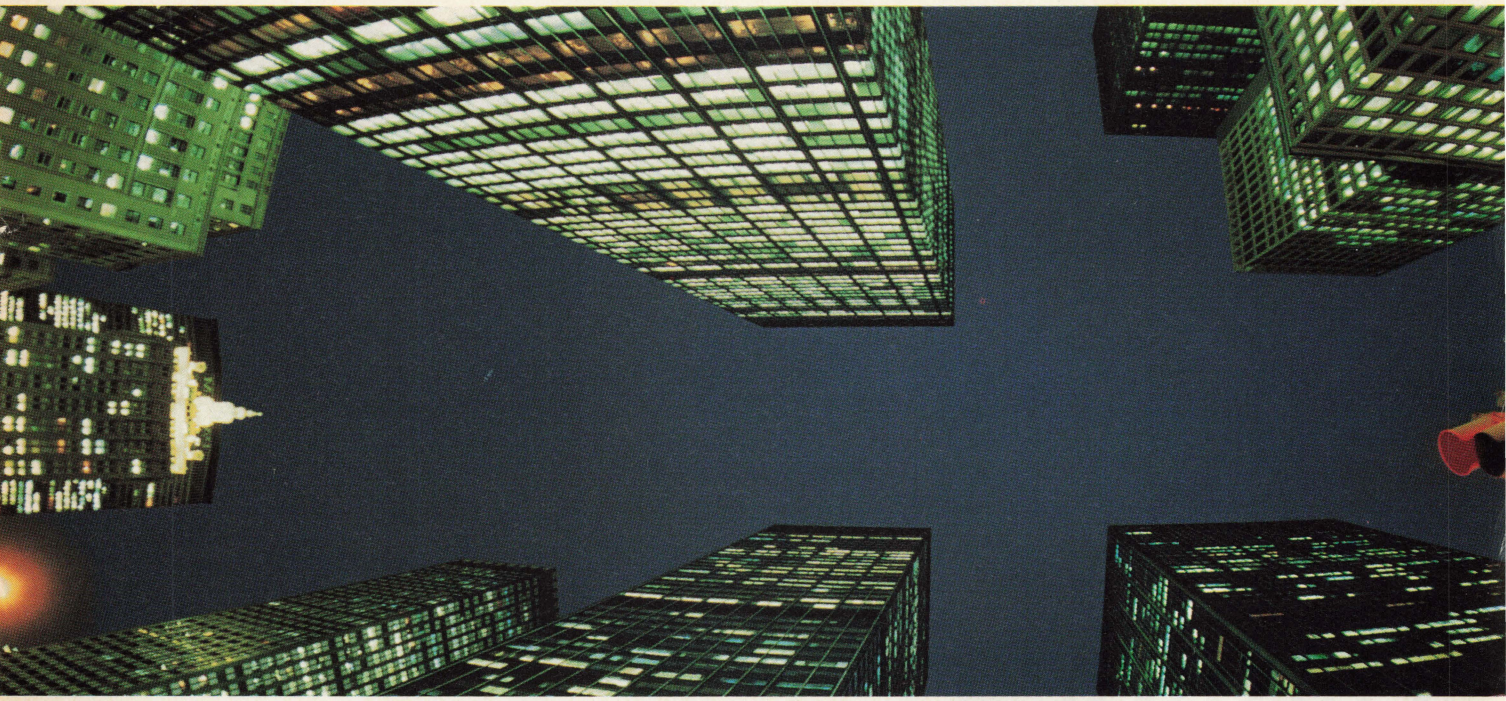

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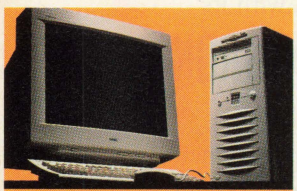

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COMPUTER GRAPHICS WORLD
INNOVATION IN VISUAL COMPUTING
Volume 22, Number 6
June 1999

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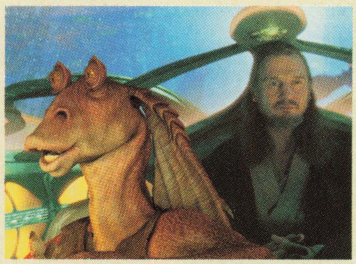
In the digitally handcrafted worlds of *Episode I: The Phantom Menace*, CG characters share top billing with human actors amid landscapes assembled from miniature sets, digital models, and matte paintings.
• *By Barbara Robertson*



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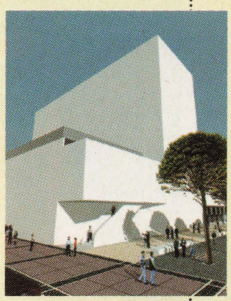

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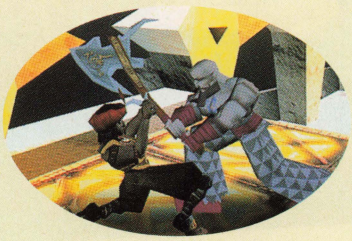
A monstrously successful game title could do for a general-purpose game engine what movies such as *The Terminator* and *Jurassic Park* did for 3D animation software.
• *By Bob Cramblitt*



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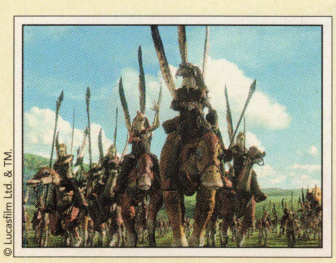

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ON THE COVER

Gungan soldiers prepare to do battle with Federation droids in *Star Wars: Episode I: The Phantom Menace.* Jar Jar (in background) is one of 66 CG characters created for the film. His actions in the battle were achieved with keyframe animation, whereas motion capture was used to animate the hundreds of Gungan soldiers and droid "extras" in the scene. For more on the film, see page 24.

Check out Computer Graphics World at www.cgw.com for the online gallery

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Editors' Choice cnet — ViewSonic G790 *October 1998*

PC WORLD TOP 10 MONITORS — ViewSonic PT775 *July 1998*

PC Computing — ViewSonic PT813 *July 1998*

WIN 100 MAGAZINE 1998 — ViewSonic VP140 *June 1998*

PC MAGAZINE Best of 1997 — ViewSonic PT813 *January 1998*

New Roles for Digital Actors

The official theme of NAB99, the National Association of Broadcasters' conference held this April in Las Vegas, was "convergence," namely, the coming together of digital technologies for the broadcast industry. But it might as well have been "emergence," for as these technologies have evolved and merged they have created a host of new opportunities.

A case in point is performance animation. This technology—which entails facial and body motion capture of live actors in real-time and the assignment of their movement to computer-generated characters on screen—has achieved a great deal of popularity on broadcast TV in Europe and Japan.

Unfortunately, the demand for performance animation on US network TV has not yet materialized. The main reason is that US broadcasters are not well-informed about the benefits it can bring to both live and episodic programming. Moreover, many fear losing the control they maintain over content with traditional animation techniques.

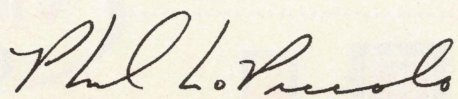
Given this reluctance, some developers believe the Web will be a promising new stage for performance animation. "The Web is going to be an important medium for this technology because there's a match," according to NAB presenter Julian Corbett, vice president of Medialab, a Paris-based performance-animation studio. Indeed, animators find the Web enormously appealing because it allows them unfettered artistic freedom, and Web developers find real-time animation desirable because it gives them unique ways to differentiate their sites from the many thousands of others.

"A lot of corporations are spending a lot of money to attract eyeballs to their Web sites and keep them there," says another NAB presenter, Steve Tice, president of QuantumWorks, developer of PC-based performance-animation systems. One of the most effective ways to grab and hold a Web viewer's attention is to update the site frequently, he notes, and because performance animation can be revised more easily than traditional animation or video, the content can be more topical and potentially more appealing.

One company that is doing daily animation on the Web today using performance animation is Protozoa, one of the early pioneers of the medium and the first to use it on the Web (check out www.dotcomix.com). "Performance animation is a good fit for the Web," says Protozoa founder Brad deGraf, "because it's much more cost-effective than other Web-animation forms, and the nature of the content allows it to circumvent bandwidth limitations by broadcasting data instead of video."

Gregory Panos, founding co-director of the Performance Animation Society (www.pasociety.org), says that all the investment flowing into the Internet may create some new opportunities for performance animation, but believes that the technology's true destiny still lies in episodic TV. "As the networks move to HDTV, there will be a huge void for digital content," he says, "and virtual characters will offer an unprecedented ability to quickly generate HDTV-compliant material using available assets."

In any case, the future for performance animation has never looked brighter. If developers seize opportunities created by the Web and HDTV and adopt new performance-animation technologies introduced at NAB from the likes of DreamTeam, Kaydara, and Play, virtual characters may soon be playing a starring role on a screen near you.



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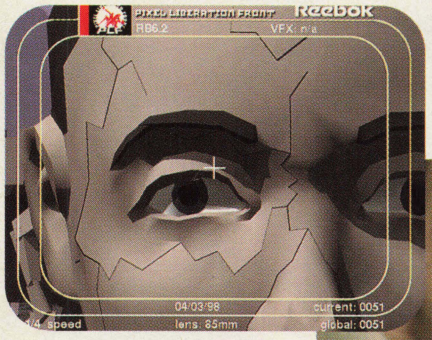

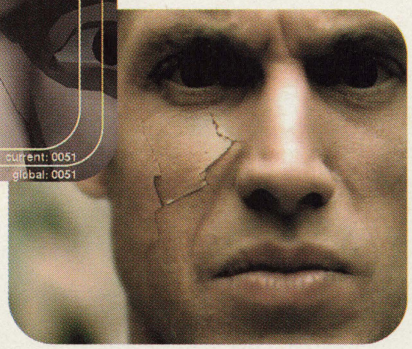

Previsualization's Prehistory

Contrary to a statement in "Sneak Previews" (December 1998; page 42), digital previsualization for the entertainment world began at least a decade before the early 1990s. From 1980 through 1989, I was employed by Evans & Sutherland, where our clients routinely used computers for applications ranging from space docking simulation to medical imaging.

In the 1980s, I know that Lucasfilm was using wireframe models running on a Digital VAX with an E&S MPS 25-inch color display to provide real-time feedback to set up motion-control shots. My guess is that the hardware to make this happen cost around $1 million, but it probably saved $10 million.

The concept of graphics simulation has been around since the beginning of the digital computer era. Take a look at Newman & Sproull's *Principles of Interactive Computer Graphics*. Like the phase-locked loop (which could not be built with vacuum tubes but is now available on one small integrated circuit), the ideas just had to wait for the hardware to catch up.

Robin McCain
Silicon Mirror
San Francisco

Author's Reply

Like many CG tools and technologies, digital previsualization was developed in the military and industrial arenas and subsequently adapted for the purposes of entertainment. As a result, digital previsualization has had comparatively more recent use in the entertainment industry. There are several reasons why.

As the reader points out, the hardware he says Lucasfilm used in the 1980s cost a great deal of money. And that figure does not include the personnel and costs associated with the proprietary software that was developed by Lucasfilm, which was required for the real-time feedback of motion-control shots. At that time, Lucasfilm was likely the only facility that could afford the cost and that required digital previsualization.

In the 1980s, digital imagery for TV and film was in its infancy. In addition to ILM (and later on, Pixar), only Pacific Data Images, Robert Abel & Associates, Omnibus, and a few other pioneers had started to create digital imagery, using slow computers and homegrown code to do so. The technology was not yet capable of the complex imagery that is the hallmark of today's digital effects, a complexity that makes a compelling case for digital previsualization. The democratization of hardware and software has also contributed to today's widespread use and acceptance of digital imagery and, consequently, previsualization, in the entertainment industry.

Debra Kaufman
Venice, CA

Character Counts

I am a university student studying math and computer science, and I've recently been considering whether to pursue further education in either computer graphics or animation.

In my humble opinion, creators of most CG cartoons are computer artists first and animators second. For example, I find the cinematography of the program *Voltron* very poor. The camera flits around far too quickly, and the scenes seem empty and cold. I also think the characters lack "character." This observation stems from watching an episode of Looney Toons the other day. One look at Sylvester hanging in midair, and I cracked up. I could relate to it, because it was exactly the kind of emotion I would have had in a similar situation.

That kind of connection is what seems to be lacking in computer graphics, so at this point, I'm leaning toward a traditional animation program. Animation should be much more important to CG artists than discovering a new way to refract light, for example. I love animation and cartoons, and I would like to see animation and technology come together... but if there's a choice between the two, for the time being, I think I'll choose animation.

Gordie Neill
York University
Toronto
Canada

More for the Mac

I would like to add Maxon Computer to the list of vendors developing 3D Macintosh applications that you cited in the March 1999 Letters column. Our Cinema 4D line offers fully integrated modeling, animation, and rendering. All our software versions—even plug-ins—are developed on a cross-platform basis so that Mac users don't miss out on Windows-only plug-ins, like some Lightwave users do.

Our next upgrade will bring functionality previously reserved for more expensive (and NT-based) products such as Softimage and Maya, and will include some features even these products don't have, and many never before seen for a Mac.

Paul Babb
Maxon Computer
Thousand Oaks, CA

Correction

In the article "VR Goes to School" in the March 1999 issue, the illustrations on pages 39 and 40 that depict an environment for learning Chinese are from a research publication, "VLT, A Virtual Environment for Learning Chinese" by Tom De Paepe, L. Ma, A. Heirman, B. Dessein, D. Vervenne, Prof. Dr. F. Vandamme, and C. Willeman; as well as from the electronic journal, *VR in the Schools* (Volume 3, number 4, March 1998). The environments were developed using Ultima-3D, Sense8's WorldToolKit, and Intergraph workstations.

We Value Your Input

We welcome any insights you may have that would further our readers' understanding of topics discussed in this issue. We may edit your response to conform to our style and space requirements.
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SPOTLIGHT

Video Toaster Comes to NT

Ten years ago, NewTek's Video Toaster for the Amiga brought video creation and editing to the desktop. Throughout the last decade, the program has continued to enjoy a robust following on that platform. Now, however, NewTek has introduced Video Toaster for NT, a suite of tools for video creation, editing, compositing, and 2D/-3D animation that utilizes uncompressed digital video, at a cost of $2995.

"With this price point, NewTek is going after a new audience—people who couldn't afford uncompressed video before," says Wanda Meloni, senior software analyst for Jon Peddie Associates (Tiburon, CA).

Video Toaster also includes the editing application Speed Razor VTE from In:Sync, the 3D animation program Lightwave VT, and Aura, a 2D paint application optimized for animation and video layering. In the future, NewTek plans to add modules for a real-time 16-input switcher, storyboard editing, real-time 3D DVE, chroma keying, and a serial D1 interface.

Recommended workstation requirements include an NT-based system with a Pentium III processor, 256MB of RAM, and a drive system capable of 22MB/sec.

The product will also be available as part of the Intergraph (Huntsville, AL) StudioZ Toaster workstation, a turnkey system based on a Pentium III 500MHz processor.

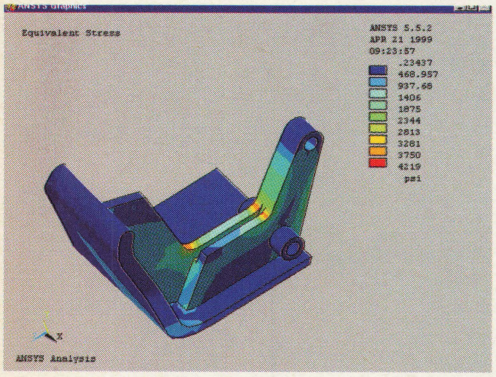
Video Toaster NT was expected to ship this month. (San Antonio, TX; 800-843-8934; www.newtek.com)

—Jenny Donelan

infoNOW 84

Analysis Made Easy

Sporting an easy-to-use interface, Ansys/Professional, a toolkit for structural and thermal simulation and the latest addition to the Ansys product line, gives design engineers access to the advanced analysis capabilities typically reserved for those well-versed in the commands and protocols of analysis software. Ansys/Professional is targeted at design engineers who may lack Ansys experience but could benefit from the ability to run this type of analyses on their designs quickly and easily.



Ansys/Professional's window into the world of analysis is its Mechanical Toolbar, a graphical user interface (GUI) that incorporates sequential tabbed menus and drop-down boxes. With this, a user can execute a complete analysis on model data imported from Pro/Engineer, SAT, Parasolids, or IGES formats by moving step-by-step across the tabs on the toolbar. Doing so requires little more programming expertise than any mainstream Windows application.

The software provides numerous advanced analytical features. As a structural application, it solves static, buckling, and dynamic analyses. It also includes such nonlinear features as large deflection, stress stiffening, and node-to-node contact. For thermal simulations, the software provides linear and nonlinear analyses for steady-state and transient heat transfer, and for evaluating conduction, convection, radiation, and phase change. To extend the "out-of-the-box" analysis capabilities of Ansys/Professional, users can access the traditional Ansys interface from the Mechanical Toolbar.

According to industry analyst Bruce Jenkins of Daratech (Cambridge, MA), "We're excited about this product because it makes the full Ansys product line more accessible to design engineers rather than just analysts. And for engineers who know about structural analysis, it provides a GUI and controls to the Ansys code."

The suggested North American list price for Ansys/Professional is $15,000. (Canonsburg, PA; 724-746-3304; www.ansys.com)

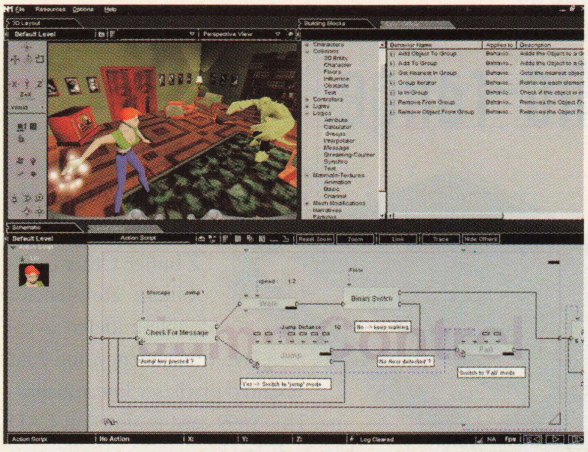
—Diana Phillips Mahoney

infoNOW 85

Behaviors To Go

NeMo Dev from Virtools allows game developers to easily prototype or simulate behaviors associated with any 3D object used in a game. The product is intended to speed up development cycles by reducing the amount of code to be written and by allowing developers to test game interactivity from the earliest stages of the development process. Developers can use NeMo to create a prototype for pitching an idea to a game buyer, for example.

To incorporate behaviors, users import 3D Studio Max or Softimage textured models and keyframe animations, or a variety of picture, video, and sound files, and attach behaviors to them. NeMo comes with a library of behaviors, and also imports existing behaviors from other sources. The finished content can be viewed by anyone using the free NeMo player. NeMo Dev also comes with a software developer kit (SDK) so that game developers can integrate the NeMo technology with existing applications, eliminating the need for a separate player.



"Virtools has a strong technical foundation in the SDK," says Jeff Yates, market manager for games and interactive at Kinetix/Discreet Logic. "They're not out to create a black box that you can't get into—it's very accessible to developers, and at a good price point, too."

NeMo Dev has been available as a custom application in Europe for slightly less than a year. The product's worldwide release (scheduled for May 1999) coincides with the shipment of NeMo Creation, a version of the product that does not contain the SDK and is aimed at graphic artists, programmers, and multimedia authors as well as game developers.

NeMo Dev is priced at $3490 for a one-seat license; the NeMo Creation package costs $990. (Paris; 33 42 71 46 86; www.nemo.com)—*JD*

infoNOW 86

3D Engine Offered in Licensing Scenario

Cycore Computers (Uppsala, Sweden) is offering Version 3.1 of Cult3D, its multiplatform 3D rendering engine, as a free download from the Web at www.cult3d.com. The software, which runs on Linux and the BeOS, in addition to better-known operating systems including Windows and the MacOS, greatly reduces the amount of code developers must write in order to produce interactive 3D objects for the Web.

Though the engine (and a viewer) are free, the company charges a $3600 fee for any Cult3D-created objects posted to a Web site. Sites now using Cult3D technology include the Nobel Foundation at www.nobel.se/prize/medal3d.html and Nokia at www.nokia.se/products/data/9110communicator/virtual9110/.

QuickTime for Java on the Way

Apple Computer has introduced a new version of QuickTime, its well-known digital media software, for the Java platform. The public beta is now available at www.apple.com/quicktime/qtjava. QuickTime for Java provides access to graphics, sound, video, text, music, VR, and 3D capabilities through an object-oriented Java framework built around the QuickTime API.

Call for Art

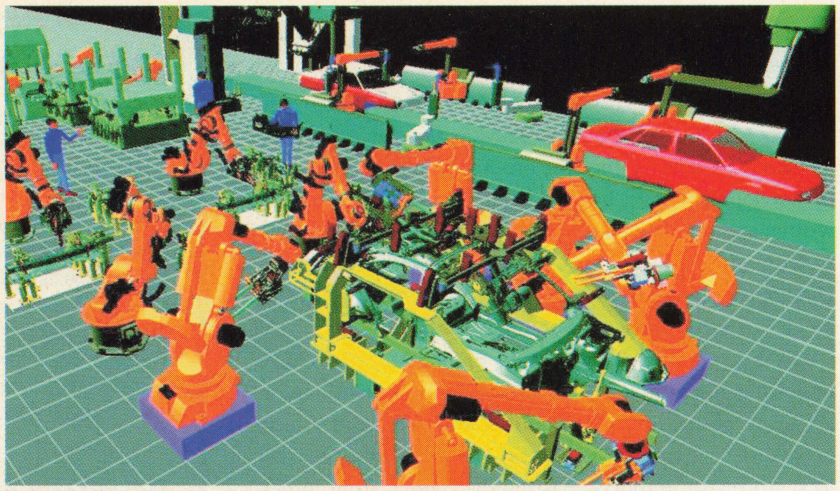
Artists can now submit their CG creations to The Scene, a Web site dedicated to providing exposure, guidance, and resources for digital artists, writers, and musicians. To submit a work, visit www.inthescene.com/submit.

In Brief

CAE software developer **Ansys** (Canonsburg, PA) has completed the acquisition of **Centric Engineering Systems** (Sunnyvale, CA).... **Dassault Systemes** (Paris) has created a new subsidiary, Dassault Systemes Provence, located in Aix-en Provence in the south of France... Dassault has also announced that it intends to acquire **Smart Solutions** (Kfar Saba, Israel), which develops PDM and workflow software... **Viewpoint DataLabs** (Orem, UT) has changed its name to **Viewpoint Digital** in the aftermath of the merger between Viewpoint DataLabs and **3Name3D** and the acquisition of both those companies by **Computer Associates** (Islandia, NY)... **Silicon Graphics** (Mountain View, CA) has changed its name and logo to **SGI**... **Siemens Automation and Drives Group** (Hannover, Germany) and **Tecnomatix** (Herzliya, Israel) have entered an agreement to create 3D virtual environments for engineering processes. The first joint product is due for release in mid-1999.... The **MacNeal-Schwendler Corp.** (Los Angeles) has created a new division, **MSC Working Knowledge,** which will focus on the development, sales, and marketing of mechanical simulation tools for design engineers.

Jenny Donelan is managing editor of Computer Graphics World.

Factories From Start to Finish



The Digital Factory from Tecnomatix provides a CAD-independent suite of tools for designing, planning, simulating, and optimizing a complete factory or smaller components, including production line, cell, and operation. The product is based on Tecnomatix's Process Model Platform, an open-architecture desktop that works with the major elements of the suite: Robcad, Valisys, Part, Dynamo, Simple++, and Exaline.

With Robcad, a factory designer can design, simulate, and optimize automated or manual manufacturing systems using 3D visualization and simulation. Valisys allows the designer to define and verify manufacturing tolerances and perform other analyses. Part is used to generate machining processes, and Dynamo to verify product-manufacturing feasibility in terms of packaging, assembly, and maintenance. Simple++ (recently updated with Version 6.0) enables the design and optimization of manufacturing plants or lines, taking into account variables such as workers, machines, tools, materials, transportation, and costs. Exaline is an assembly line management tool that can be used to reduce cycle time and increase productivity.

The price of the Digital Factory and its components is determined according to each client's configuration. (Herzliya, Israel; 248-471-6140; www.tecnomatix.com) —*JD*

infoNOW 87

Board Makers Aim for the Mid-range

A bevy of new Pentium III-optimized 3D graphics accelerators for NT-using professionals has hit the market. Alternatives between entry-level ($200 range) and high-end ($1500 plus) boards used to be scarce. Now vendors are aiming for a new "sweet spot" with sub-$1000 cards targeted at mid-range professional users.

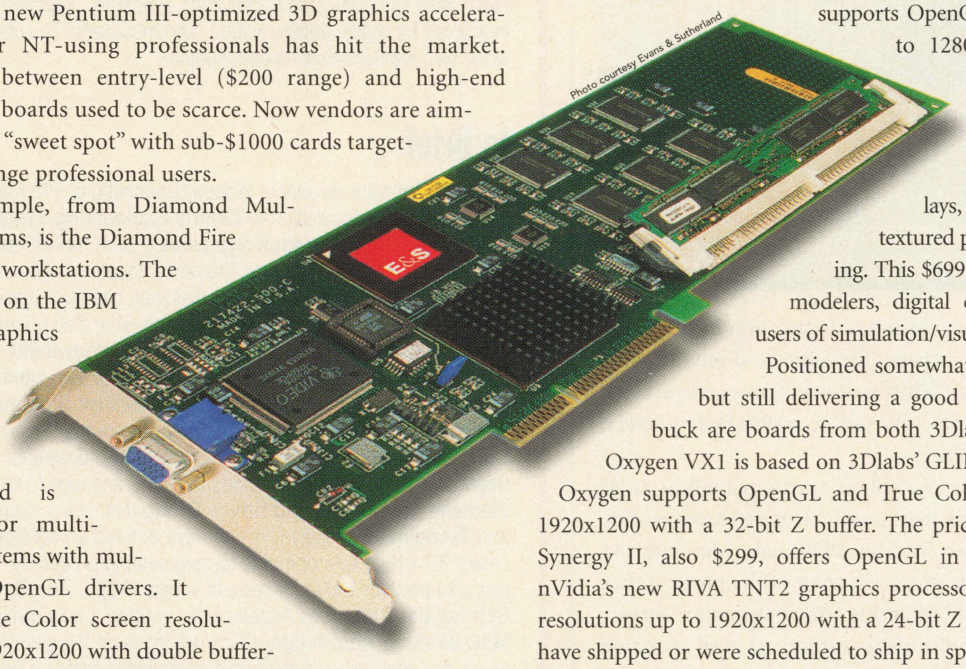


Photo courtesy Evans & Sutherland

One example, from Diamond Multimedia Systems, is the Diamond Fire GL1 for NT workstations. The card is based on the IBM 256-bit graphics rasterizer, the first such engine for the NT market, and is optimized for multiprocessor systems with multithreaded OpenGL drivers. It supports True Color screen resolutions up to 1920x1200 with double buffering and a 24-bit Z-buffer, for a price of $995. The Fire GL's target market comprises 3D animators, CAD engineers, and Web content creators.

Also entering the mid-range arena is Evans & Sutherland with its Lightning 1200, based on E&S's REALimage 1200 chipset. The board supports OpenGL and resolutions up to 1280x1024, with double buffering and a 24-bit Z buffer. Other capabilities are stencils, double-buffered overlays, transparency, and 70M textured pixels/sec line antialiasing. This $699 card is aimed at CAD modelers, digital content creators, and users of simulation/visualization applications.

Positioned somewhat closer to entry level but still delivering a good deal of bang for the buck are boards from both 3Dlabs and Elsa. 3Dlabs' Oxygen VX1 is based on 3Dlabs' GLINT R3 processor. The Oxygen supports OpenGL and True Color resolutions up to 1920x1200 with a 32-bit Z buffer. The price is $299. Elsa's new Synergy II, also $299, offers OpenGL in hardware, based on nVidia's new RIVA TNT2 graphics processor. The card supports resolutions up to 1920x1200 with a 24-bit Z buffer. All these cards have shipped or were scheduled to ship in spring. —*JD*

(Diamond Multimedia Systems; 408-325-7000; www.diamondmm.com) **infoNOW 88**

(Evans & Sutherland; 801-588-1000; www.es.com) **infoNOW 89**

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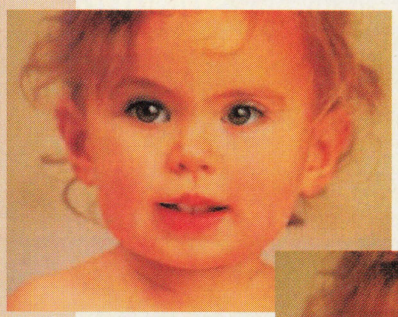
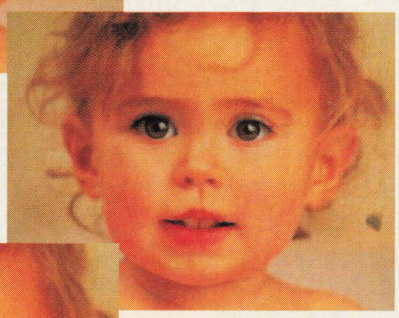
It's All in How You Say It

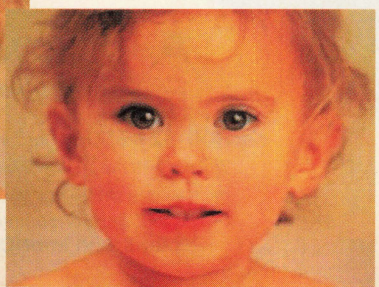
To animate a digital Mona Lisa, the Voice Puppet applies facial-control parameters that have been "learned" through a computer-vision analysis of video footage of a person speaking.

Realistically re-creating human motion is still considered one of the unexploited frontiers in computer graphics. Reproducing human facial motion is a particularly challenging quest, considering the seemingly infinite number of expressions a given face can assume and the fact that such expressions are a function of many variables, including facial anatomy and speech patterns. To be sure, there have been remarkable achievements in the human facial-animation area in the past few years, but typically at the cost of significant blood, sweat, and tears on the part of the animators.

An innovative system being developed by researchers at the Mitsubishi Electronic Research Laboratories (MERL) in Cambridge, Mass., has the potential to give some of these overworked animators a well deserved break. Called the Voice Puppet, the system drives facial animation directly from vocal cues. The "gadget," as developer Matthew Brand refers to it, watches a video of someone talking or singing, then, using computer-vision techniques, "learns" how the face moves by tracking certain features. "It tracks a lot of points around the mouth, eyes, cheeks, nose, chin, hairline—anything. It can capture the wiggling of ears if that's what you care about," says Brand. The system then outputs a series of facial-control parameters that can be used to drive many kinds of animation.







Kids say the darndest things, especially when the Voice Puppet is driving their words and expressions using the voice of one adult and the facial mannerisms of another.

In addition to learning how the face moves, the Voice Puppet also learns how information in the audio track of the video it's training on predicts motions in the face. "Certain sounds are related to certain expressions. The nifty thing from a science point of view is that [sound/motion correspondence] is not one-to-one, it's many-to-many. There are lots of face poses that are consistent with one sound, and there are lots of sounds consistent with one face pose or motion. The Voice Puppet figures out an optimal sequence of facial motions," says Brand.

In practice, the Voice Puppet can be trained on any person—Brand uses the ultra-expressive Robin Williams as an example—and a user can then put his or her voice through it to produce facial motion that looks like Robin Williams' style, complete with his trademark facial mannerisms. "It generates the motions, then we can do almost anything with that. We can make a baby talk with my face and Robin Williams' facial manner, for example. We've tried it on everything from 3D barn animals to all the presidents to the Mona Lisa."

The Voice Puppet is fundamentally different from typical facial animation systems that create facial motion by matching a stream of basic sound tokens, called phonemes, to facial poses, or visemes. Such an approach does not take into account the subtleties of facial gestures, nor can it handle the difficult issue of co-articulation, whereby different parts of a person's face and vocal tract move at different speeds. "The muscles in the lips and vocal tract are fast, while the muscles in the face are slow. The brain compensates for this, and gets facial tissues into place in advance of when you're going to make the sound. That changes the way things sound a few sounds away," says Brand. Essentially, this means that what a person's face is doing at any point in time doesn't just depend on the sound the person is making right now, it also depends

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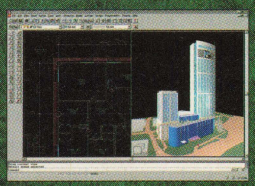

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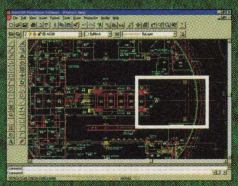

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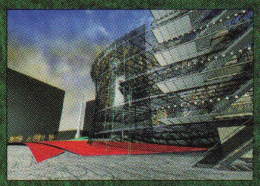

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on the sounds he just made and is about to make. The Voice Puppet is able to account for this phenomenon, says Brand. "[With the Voice Puppet] you can get arbitrarily close to reality the more training the system gets."

Additionally, the Voice Puppet focuses on the entire face rather than just lip-syncing. "It can pick up the emotional content of your voice and [the relative expression in] your eyes, eyebrows, hairline, and so forth. If you train it on someone who has a double chin, for example, it will figure out how the fat under their chin moves when they speak," says Brand.

Also unique is the fact that the Voice Puppet generates a palette of saved facial styles. "You could say, 'I want Robin Williams' style,' or you could pick something out of an old film—maybe you'd want it to learn to move someone's face like Fred Astaire moved his—then you could save that style and choose it when you wanted it." To apply a style, the system generates the motions of vertices that can be mapped onto combinations of morph targets. These can drive a 3D model directly or they can be mapped to warps of a picture, depending on the application.

The obvious application for the Voice Puppet is in the entertainment area. "We can do much better [in terms of accurate facial animation] than what people do for movies like *Antz*, and we can do it in a few minutes. It takes as long as the utterance to do it, so if you want to have two hours of speech, we can record it and animate it in four hours," says Brand. Once the system is refined, Brand is confident it will move quickly into movies and TV special effects.

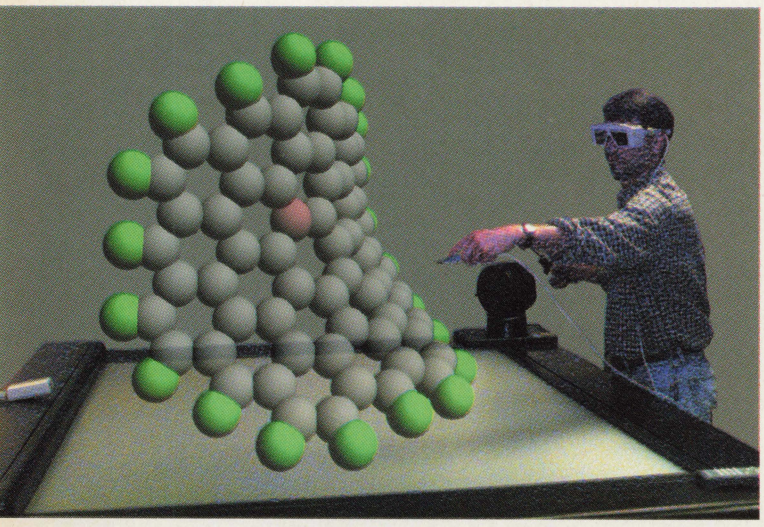
The Voice Puppet is not all fun and games, though. Scientists are using it to study how the human face works, and Brand foresees application of the tool as a communication aid for stroke victims and others who have trouble controlling their faces because of neurological damage. "I'm interested in generating avatars of these people and training the system on a home movie of the person before the stroke. When they speak, it would generate their [Avatar's] face with their old set of facial mannerisms. It would restore some of their powers of expression," says Brand.

Brand is in the process of determining a commercial avenue for the Voice Puppet. "I'm basically a scientist, so I have to go on and do the next publishable thing, but I hope to partner with a firm that has an animation package and do a plug-in for them." The current iteration of the Voice Puppet is scheduled to debut at SIGGRAPH '99 in Los Angeles in August.

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

Atomic Discovery

To physicists and other scientists, the concept of nanotechnology looms in their vision as a sort of Holy Grail. They know that the ability to manipulate matter with atomic precision will bring huge gains to just about any manufacturing process that employs the approach, and they are going to great lengths to figure out how to translate the concept into practical application. A major obstacle in their path, however, has been the fact that atomic behavior cannot be observed directly. Although the most powerful microscopes can provide a peak into atomic worlds, they are not capable of capturing the detailed nature of atomic motion and interaction.



The simulated molecular structures of a graphite sheet are brought to life with the Virtual Mechanosynthesis (VMS) utility, enabling the user to see, move, and feel the carbon (gray) and hydrogen (green) atoms.

In an attempt to barrel through this roadblock, researchers in NASA's NAS data analysis group have developed a new visualization system that enables users to see, move, and feel simulated molecular structures in three dimensions.

Called Virtual Mechanosynthesis (VMS), the system couples an accurate molecular dynamics simulation code to an immersive, interactive graphical display. "I wanted life-size atoms to play around with—like holding up a couple of grapefruits in front of me—and I wanted them to behave realistically," says Chris Henze, who created VMS with colleagues Bryan Green and Creon Levit. The utility provides bi-directional interaction between the visualization and the simulation. "As the simulation runs, it updates the visualization. And interacting with the visualization influences the simulation itself," says Henze. "You apply force to move one of the atoms around, and that's forwarded to the simulation code, which takes that force into account and moves the atom that you're pushing, and also indirectly moves all the other atoms."

The developers believe that VMS will provide a valuable window into nanotechnology, specifically into the "how-tos" of building a nanoassembler—a device that will actually manipulate atoms. "Say you have 100 bottles with each of the elements in them. You'd program this [nanoassembler] to put a certain number of atoms of each element together to build what you want. With a machine like that, you could build anything," says Henze. Building the machine itself, however, is fraught with challenges. "There's a huge technical problem. Since you're building up this nanoassembler sequentially, you have to make sure all the intermediate structures are stable and don't go flying apart. And on the software side,

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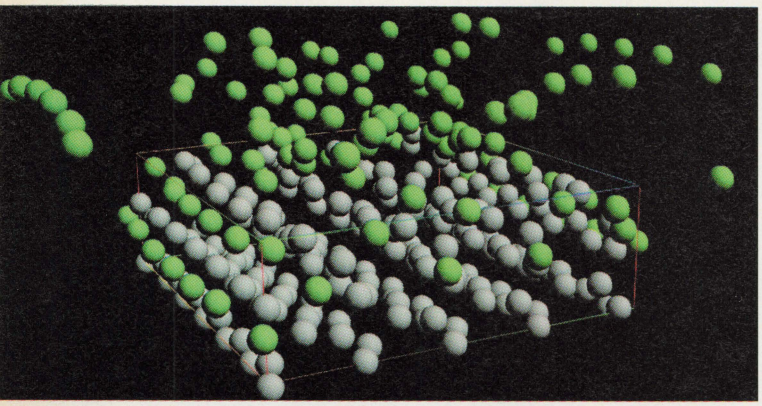

A VMS display shows the atomic behavior of a piece of hydrogen-terminated diamond. The hydrogen atoms (green) are starting to boil off.

how in the heck do you program this machine? Whatever you want to build, you're going to have to give this thing some humongous program that it's going to execute."

Henze and his colleagues believe VMS will provide insight into the principles of writing those kinds of programs. "Since we can actually start to build structures and see how the atoms work and act, we can start figuring out atomic engineering principles to get ideas about what kinds of configurations hold together," says Henze.

The graphical representations of atomic configurations using VMS is fairly simple, consisting of shaded spheres that Henze "cooked up" in C++ and OpenGL. "There's actually a lot of different ways you could handle the [graphical] display, but this is the most straightforward," says Henze. Because real atoms are submicroscopic and vibrate at almost undetectable frequencies, the VMS visualizations scale up space by nine orders of magnitude and slow down time by 15 orders of magnitude. Using various interactive and navigational tools, users can explore the resulting images from entirely new perspectives. Driven by an SGI Onyx2 engine, VMS displays atomic structures on an Immersive Workbench mirror-based display system from Fakespace. Shuttered glasses receive signals from a Crystal Eyes emitter to provide an active stereo view of the scene, and a head tracker strapped to the glasses updates the display as the user's head moves. A Polhemus hand tracker serves as a 3D mouse of sorts, controlling a cursor that floats around in the scene. The user can grab and move the cursor to change the viewpoint of the entire scene and to select and study individual atoms. When a user selects an individual atom, that atom becomes the focal structure of the scene and responds to the user's hand movements. "The simulation takes into account the changing position of the selected atom and generates a physically accurate response among the other atoms in the scene," says Henze.

VMS also incorporates a Phantom haptic device from SensAble Technologies, which provides force-feedback from the interactions. Integrating this component into the system was particularly challenging, says Henze, because the haptic device updates at a rate much higher than the update rate of the forces from the molecular simulation. "If you've got a couple hundred atoms, you're only doing the simulation updates at about 20 or 30 times a second. The Phantom update loop runs at 1000 times a second. So you have to cut in every 30 or 40 haptic update loops and give it a new force," says Henze. Doing so, however, results in significant aliasing. "You get this horrible oscillation, especially if you're pushing an atom right around its bond link. If you push the atom too close to another atom, you experience this big repulsive force. If you get a little too far, you get this big attractive force. So it ends up wobbling back and forth right around the bond link and completely ruins the effect."

To compensate for this effect, the researchers couple the haptic device to the focal atom indirectly with two springs and an intermediate mass. In essence, the setup serves as a low-pass filter that transmits the user's force indirectly to the focal atom. The force from the atom, however, is transmitted directly to the user, without the spring apparatus. "When you move the haptic device, it pushes on this virtual spring, which pushes on another big mass that feels like a giant bowling ball. This pushes on the focal atom with the other spring. So you push this bowling ball around in space and it damps out any oscillations," says Henze. "It's sort of a hack, but it works," says Henze.

In addition to its application in nanotechnology research, VMS is a natural for educational applications, says Henze. "Several people I'm working with now are interested in VMS for teaching chemistry. Professors want to be able to give this to their students so they can play around with virtual atoms and learn the principles of bonding."

Diana Phillips Mahoney is chief technology editor of Computer Graphics World.

ON THE HORIZON

IBM Chip Solution to Boost Interactive TV

Digital television set-top-boxes are considered critical to the next-generation of interactive entertainment and e-commerce, and a new development by IBM may be just as critical to the proliferation of set-top-boxes. The company has integrated many of the components of a digital TV set-top-box onto a single chip, a move that will lower the cost of manufacturing these devices and allow cable and satellite companies to offer such services as interactive digital TV and Internet access from a standard TV set. The new chip combines a 401 PowerPC engine, MPEG audio and video decode systems, on-board caches, and an on-chip memory. By minimizing the workload of the on-chip PowerPC 401, the new architecture makes more MIPS available for interactive services. Integrated peripheral interfaces, such as smart card, serial, and parallel ports, will ease the development of set-top designs.

Intel Designs Low-Cost Chipsets

In an effort to cut PC costs, Intel has developed a new chipset that will take over the functions of more expensive dedicated processors for certain tasks. Called the 810, the new chipset adopts an integration strategy pioneered by Cyrix, a subsidiary of National Semiconductor Corp., whereby it absorbs functions that formerly required multiple chips. An example the company provides is the ability of an 810-equipped PC to display feature films from a storage drive without using special processors. The company expects the new technology will cut the cost of PCs by up to $100.

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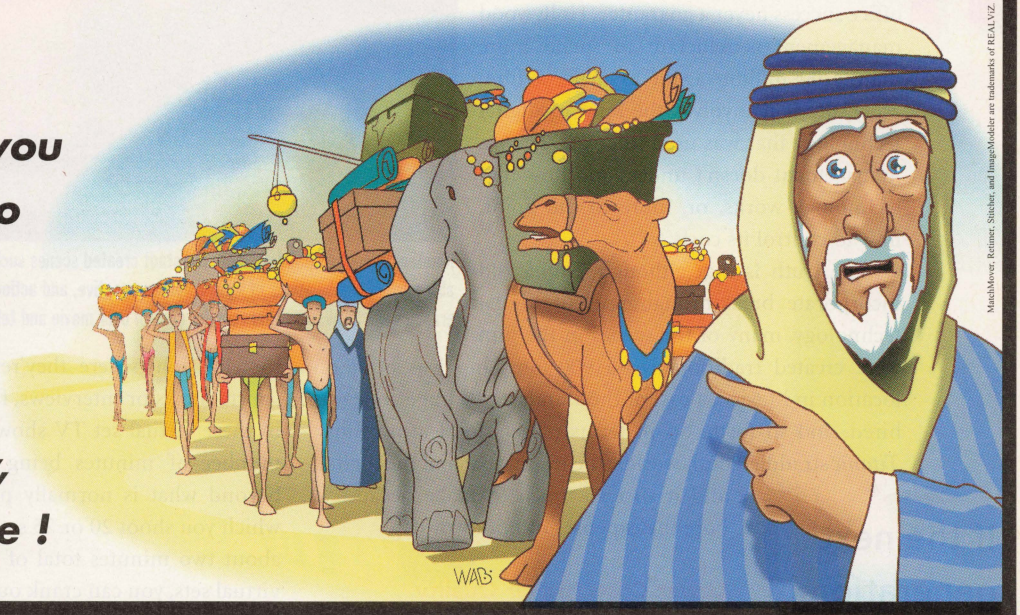

Combining live-action footage with computer-generated models is tedious, time consuming work that contributes significantly to animation costs. Precisely matching the camera motion of live-action footage in 3-D models to create the correct perspective can take weeks for an image sequence of only a few seconds. For the first time, mixed 2-D and 3-D image sequences can be created quickly and cost-effectively using cameras in motion. Using **MatchMover®** from REALVIZ, the complete live-action camera path and internal camera parameters can be computed and verified in a single application with practical, easy-to-use post-production techniques. The camera data can then be exported to compositing and animation software where new image sequences can be created using mixed live-action footage and 3-D objects and special effects.

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The Virtues of Virtual Sets

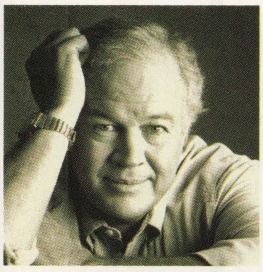
Most people know that *Titanic* was the largest grossing movie ever, and that it was the most expensive to produce. What is less well-known is that even though it has made a great deal of money, the film has effectively halted the production of digitally made, effects-laden event movies. With box office success never a guarantee, Hollywood management is reluctant to spend more than $100 million again to make a film, especially if it involves the kind of digital technology that was used to create *Titanic*. Management doesn't understand how that technology works, or, more to the point, how to control its costs.

Corbis

Nineteenth-century painter Albert Bierstadt created scenes such as "Valley of the Yosemite" with improbably perfect combinations of light, color, perspective, and action. Virtual sets incorporating computer graphics will allow filmmakers similar control over movie and television productions.

The truth is that although *Titanic* did incorporate breakthrough uses of digital technology, many of the scenes in the film were created traditionally—a 900-foot ship was built on location in Mexico, a cast of thousands and a huge crew was hired, and so forth. So in terms of sets for feature films, *Titanic* straddled both worlds, the traditional and the digital, and it cost so much to make because it bore the expenses of both worlds.

If the next generation of action-packed, effects-laden feature films is to be made, their sets will have to be digital



BY DOUGLAS TRUMBULL

Lower Cost, Higher Quality

If, however, we leave behind us completely the world of traditional sets, and instead fully embrace their digital counterparts, we can start figuring out how to take best advantage of the technology. Doing so will dramatically reduce film-making costs, and at the same time, increase production values.

Virtual sets reduce expenses because you don't have to transport your whole crew to a particular location—just send a few people to scan or capture the location and bring it back to the studio environment. Because you don't need a terribly large set in terms of physical space, you don't have to use a great deal of lighting, and you don't need many grips. In general, there are fewer things to move, build, maintain, paint, and plaster.

Virtual sets can also reduce a film's schedule, as has already been demonstrated in the broadcast arena. (For the time being, virtual sets are still largely restricted to television, where they're being used as backdrops for sports shows or interviews, for example.) What we're seeing in these virtual set TV shows is an absolutely phenomenal number of minutes being cranked out every day—way beyond what is normally produced for a feature film, in which you shoot 20 or 25 setups daily, and end up with only about two minutes total of finished footage per day. With virtual sets, you can crank out not only minutes but possibly hours of finished production in a given day.

Additional time- and cost-effective measures are possible when you combine a digital set and an electronic camera. In a virtual scenario, before shooting, before even starting to work with the actors, you can do a run-through with a bare-bones stage, a crew of only four or five people, and a cast that's just a placeholder for your real cast. After you've done that run-through, taped it, and performed a quick-cut non-linear edit, you have a finished draft to critique. With it you'll be able to find out why a story doesn't work, what's wrong with the dialog, and how a character needs beefing up *before* you've spent the $100 million.

Quiet on the Set

Once a movie is in the process of being made, all the information about each shot will be recorded as metadata, so that two days or weeks down the road, when a director complains about missed shots, the set can be up again in minutes. With a couple of switches you'll be back to the same set and the same lighting. This sort of capability should go a long way toward reducing directors' stress. At present, directors often must shoot knowing that a particular set or location will never be available to them again.

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Another stress reducer concerns actors and their schedules. Imagine you're the director of a virtual set show. Just as you're ready to begin shooting for the day, you realize that something is wrong with the set—the doors are in the wrong place, for example. And Harrison Ford, who is standing in front of you, waiting, wants to get to the Lakers' game. But you don't have to be concerned, because you know that as long as your shot is more or less framed correctly, all you really have to concentrate on is the actor himself—his performance, hair, makeup, and so forth. You don't need to worry about the placement of those doors, because they can be fixed later on. When you're able to work with that kind of confidence, shooting is going to go quickly.

Corbis

A detail from "Valley of the Yosemite" illustrates the kind of rarified light and scenery that filmmakers using computer graphics will be able to achieve without even leaving the studio.

Reduce, Reuse, Recycle

Once you've finished shooting a film, you won't have to destroy your set, as is now routinely done in Hollywood. All that plywood, plaster, and wood usually gets bulldozed and sent to a landfill. Virtual sets, on the other hand, are digital assets that can be used over and over again.

In some ways, the archiving of digital sets is similar to the way Hollywood used to operate in the 1930s and 1940s. Back then, every studio back lot had a Western street where hundreds of Westerns were made, a New York City street, a European street, and so on.

Consider also the value of your digital inventory in a world where companies constantly seek to maximize every intellectual property. A feature film is never enough—you also have to make an Imax 3D version of it, an Internet site, licensed merchandise, a television series. By making the bulk of the project digital and resolution independent, it can all be redeployed and even predeployed.

New Tools Needed

In order to make digital sets a reality, however, we do need some kinds of equipment that are not quite available yet. Among these are powerful digital cameras, a way of getting the data out of the camera into some kind of disk array, and a way of unloading the array in non-real-time. We'll also need a specially equipped stage, one of the more cumbersome aspects of which is an automated lighting grid.

We also need more capable software, because powerful as some of today's programs are, we're still limited to a world of polygons, texture maps, and splines. And this new, powerful software needs to be easy enough for an art director or a production designer to use without having to be a cyberspace expert.

But fortunately, new technologies are emerging for what we call image-based modeling and rendering, which involves a camera that gathers Z-depth information. This kind of camera can quickly scan a location and get out of it not just the colors and the texture maps, but the dimensional information as well, so that we can modify a scene by, for example, stripping all the air conditioners from a building's walls, or putting the dirt roads and cobblestones back into Time Square in New York City.

A Digital Cinematic Future

Once we have all these tools, we can take the world, sample it, de-construct it, then put it together in a new way, very much like the music business does now so successfully with sound. Then it will be possible to reconsider those movies currently stalled in Hollywood—the ones budgeted at $100 million or more. If studios can make these movies for half as much, they will. And they'll achieve just the same quality of production as before—probably even better. Because with virtual sets you can build things no production designer can physically build. The weather can be exactly as you want it all day long, and you can be in "magic light" for weeks—not just a few minutes in the morning or evening.

Using a virtual set, you can shoot in "magic light" for weeks, not just for a few minutes in the morning or evening.

This is all doable within the next couple of years, and at Entertainment Design Workshop we are putting together the elements now. We will have photorealistic, composited, quality material for feature films, a method that will work for TV and other media as well. It's going to save tens of millions of dollars on every production.

Douglas Trumbull has been involved in special effects for films since 2001: A Space Odyssey *in 1968. He is president and CEO of Entertainment Design Workshop in Sheffield, Massachusetts.*

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STAR

USING DIGITAL TOOLS TO HAND

IN *EPISODE I: THE PHANTOM MENACE*, MORE THAN 800 SHOTS FEATURE DIGITAL CHARACTERS WITH SPEAKING ROLES, TO HELP TELL THE STORY OF A TIME LONG AGO, AND A GALAXY FAR, FAR AWAY

BY BARBARA ROBERTSON

It's huge. For *Star Wars Episode I: The Phantom Menace*, George Lucas, writer, director, and producer (with Rick McCallum), transported a universe from his imagination onto film, with a richness of visual detail not seen before in a science fiction film. By integrating techniques often relegated to post production right into the heart of the movie, the people at Lucasfilm and at Lucas Digital's effects division, Industrial Light & Magic, have handcrafted a film unlike any other.

Ninety-five percent of this movie is digital. Actors mingle with digital characters, puppets, and people wearing "rubber heads;" and they all move through landscapes and cities on three planets, Tatooine, Coruscant, and Naboo, which have been assembled from bits and pieces of live-action footage, miniature sets, digital models, and matte paintings. Machines are sometimes physical models, sometimes digital models, sometimes background paintings. Water, dust, fire, and smoke might be real elements in a digital environment, or digital elements in a miniature set. At ILM, the artists, technical directors (TDs), and animators used every computer graphics technique in the shop, and when those weren't enough, they invented new ones. "This is the digital back lot George [Lucas] talked about," says Barry Armour, a CG supervisor.

In this prequel to the legendary *Star Wars* trilogy, we meet Anakin Skywalker (actor Jake Lloyd), the young son of a slave, who will become the dreaded Darth Vader in later episodes. Anakin lives on Tatooine, a desert-like planet filled with gamblers and outlaws, where wealthy slave-owning gangsters make money in the black market. All this is illegal in the Galactic Republic, but the criminals in this recently colonized, outer-rim territory find little opposition.

The center of the Galactic Republic is Coruscant, a planet covered almost entirely with skyscrapers and spaceports. It's the seat of galactic government, the power center. Coruscant's capital, Imperial City, is home

Jar Jar Binks and his guards (all members of the Gungan race) are three of the movie's 66 digital characters.

Credit for all images: © Lucasfilm, Ltd. & TM

Watto

The unique physique of this junk dealer from the planet Tatooine presented challenges for modelers and animators.

Jar Jar

Appearing in 350 shots, this digital sidekick to the Jedi Knights was created by modelers and animators at Industrial Light & Magic.

four new digital stars

WARS

CRAFT A FANTASTIC WORLD

to the Jedi Temple where the Jedi Council ponders the fluctuations of the Force, tests recruits, and monitors its far-traveling Jedi Knights. As the movie begins, two of these guardians of peace and justice—Obi-Wan Kenobi (Ewan McGregor), a determined young Jedi Knight, and Qui-Gon Jinn (Liam Neeson), his venerable Jedi master—have traveled to a spaceport orbiting Naboo to negotiate an agreement with the Trade Federation, which is threatening to blockade and invade the planet.

To help animate the robes worn by Boss Nass and the other Gungans, ILM's R&D department created a cloth simulator.

Boss Nass

For this Gungan King, animators used reference footage of actor Brian Blessed and adopted many of his mannerisms.

Sebulba

To animate the bits dangling from this pod racer's chin, a simulator was called into action. His performance, however, was key framed.

Dozens of Digital Characters

The garden-planet Naboo is made of rocks thousands of miles in diameter, surrounded by caves. Swampy lakes, open sea, and land masses rich with vegetation cover the surface. Naboo has two separate, highly advanced cultures. Most Naboo people live in the beautiful capital city of Theed and are governed by the young, elected Queen Amidala, played by actress Natalie Portman. (In later episodes, she marries Anakin and they have twin children, Luke and Leia Skywalker.) The Gungans, an amphibious race who live in domed, underwater cities on Naboo, are ruled by Boss Nass. This entire race was created at ILM with computer graphics tools, as were several Naboo animals.

When Qui-Gon's and Obi-Wan's negotiations in the orbiting spaceport fail, they go to Naboo to warn Queen Amidala. Their landing sets off a stampede of CG animals. In the longest shot in the stampede, 61 of these strange-looking animals (from six different species) emerge from a swamp running wild-eyed and scared. Each creature has skin that jiggles as the animal runs or stamps its feet, and each has facial expressions. "Their lips move up and down with their heads," explains Marjolaine Tremblay, lead animator. "The stampede is only a couple of shots, but it's important because it happens when Qui-Gon and Jar Jar first meet." They meet by literally running into each other. Jar Jar Binks, like all Gungans, is a loose-limbed, computer-generated character that looks a little like a lizard but has the mouth of a duck, eyes on top of his head, and ears than hang down to his waist. With actor Ahmed Best providing his voice, Jar Jar henceforth travels through the movie alongside Qui-Gon and Obi-Wan, providing comic relief as their well-meaning but clumsy sidekick whose mistakes often turn out to be helpful. "He's a little bit confused, but he tries to keep up," says Rob Coleman, animation director.

Jar Jar is one of many computer-generated characters in *Episode I*. "Most of the nonhuman characters are CG," says Coleman. "They're right in the fabric of the film. The camera doesn't even always focus on them; sometimes they're in the background." There are 66 CG

Surrounded by digital characters, Qui-Gon Jinn (Liam Neeson) banters with Watto, who has lifted himself high enough off the ground to meet the Jedi Knight face to face. Watto's wings are a blur as they work hard to hold him up. To Qui-Gon's left is Jar Jar. To Watto's right is Sebulba, who uses his feet as hands and walks on his forearms.

characters and creatures in the film (plus 33 variations of them). Ten talk, and six have full lip sync, according to Coleman. The talking characters appear in 812 of the film's approximately 1900 shots.

In addition to Jar Jar, Coleman singles out three other main CG characters: Sebulba, a pod racer on Tatooine; Watto, a junk dealer on Tatooine; and Boss Nass, the king of the Gungans on Naboo. Actor Ray Griffiths provides Sebulba's voice, Andy Secomb provides Watto's, and Brian Blessed speaks for Boss Nass. The total number of shots for these characters ranges from 40 to 80, a number that, when compared to Jar Jar, causes Coleman to classify them as having "cameo" roles. As the self-imposed sidekick for Obi-Wan and Qui-Gon, Jar Jar stars in 350 shots.

The animation for all four characters was accomplished with several techniques. Each human-type character in the movie wears clothes, sometimes several layers, which were animated using procedural animation and simulation. In addition, procedural animation, dynamics, and simulation programs were used for certain elements such as Jar Jar's long ears and the phone cord hanging from Watto's waist. "The simulation gives the characters extra realism," Coleman says. "This isn't an all CG environment. Our CG characters are in the real world dealing with physics."

The animators, however, used keyframe animation to act out each character's performance, and shape blending to create facial expressions and lip sync. For performance animation, they relied on Avid's Softimage 3D; for facial animation, they used ILM's own Caricature software. All of these programs run on SGI workstations. "These fully digital characters have to hold their own in scenes with actors like Liam Neeson and Ewan McGregor and be as believable without calling attention to themselves. That requires a subtlety of performance," Coleman says

To organize the work, Coleman divided the animation crew, which fluctuated between 30 and 45, into teams. Fifteen animators worked on Jar Jar, two to three on Sebulba, four to five on Boss Nass, seven on Watto, and between five and 10 on the droids. There are nine CG droids (robots) in *Episode I*, with 12 variations; they appear in 250 shots. The droids are animated with a combination of keyframe animation for the "hero" droids and motion capture for the rest.

Behind Watto, seated in the stadium and walking on the ground, are thousands of digital people.

CG Stars

To help animate Jar Jar, the team could refer to video footage on location of Ahmed Best, who provided Jar Jar's voice. "We'd block out the performance with Ahmed in the shot, and then we'd get a clean plate," Coleman says. "It saved weeks and weeks of production time." The animators also followed directions from Lucas. "George described Jar Jar as not having any bones," Coleman says. Senior animator Kim Thompson adds, "George would say, 'Dare to be dopey.'"

To animate Jar Jar's long, floppy ears, the R&D group developed an algorithm that would move them automatically, thus relieving the animators of the task. In one scene, for example, when Jar Jar spins his head around, his ears wrap around his neck. "There are so many shots," Thompson says, "if we can get away with not animating something like that, we have more time to con-

For this exterior shot of Theed, capital of Naboo, ILM artists combined a miniature set with digital elements; for the waterfalls, they used salt. Interior shots are the opposite: digital with some practical elements.

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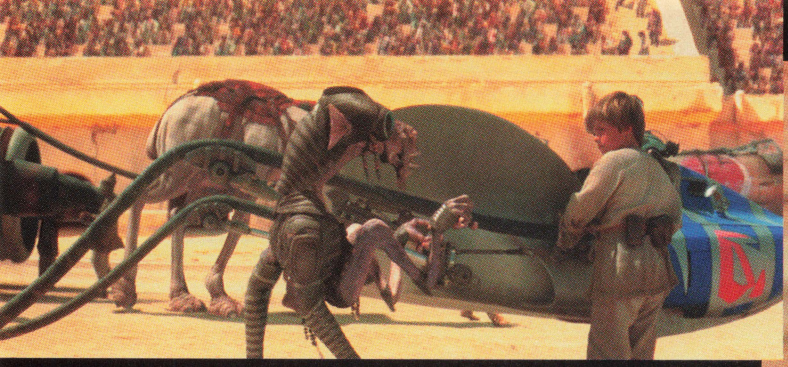
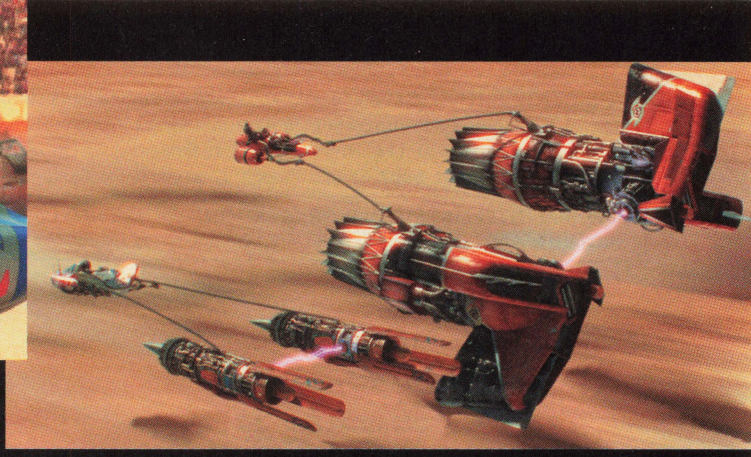




On the ground, the pods are physical models. In the race, they're CG models traveling 600 mph over miles of terrain generated on the fly by an adaptive optimized terrain program created in ILM's R&D department.

centrate on the performance." Similarly, for the innermost layers of Jar Jar's costume, CG supervisor Doug Smythe wrote a program that automatically generates displacement maps to create wrinkles as Jar Jar moves. A cloth-simulation program created in the R&D department moves his outer layers of clothes.

The cloth simulation was also used for Gungan leader Boss Nass's costume, a long, flowing robe. To create a performance for the jolly king, the team borrowed actor Brian Blessed's mannerisms. "The way he wiggles his fingers is from Blessed," says animator Hal Hickel. Adds Coleman: "There's jowly stuff that comes straight from Brian. You're truer to the character if you can use the face that produces the sound." The spittle that flies out of Boss Nass's mouth when he shakes his head, though, is a practical, filmed effect—it was composited into the scene after the character was rendered.

Even though he looks quite different from Jar Jar, he's also Gungan, so Boss Nass's model is a Jar Jar derivative. "We started with the same mesh," says Geoff Campbell, model supervisor. Other Gungans derived from the Jar Jar model include guards, calvary, civilians, and an old soldier known as Captain Tarpals.

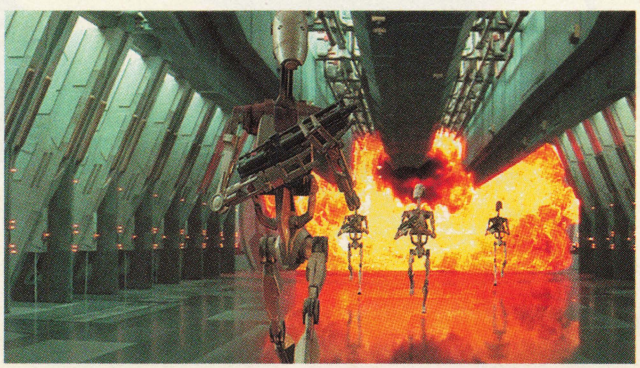
All told, Campbell supervised the work of 18 modelers who created more than 200 models for *Episode I* and, in addition, all the facial expressions and lip sync libraries for the six main talking characters. The models were created with Alias|Wavefront's Power Animator, and the shape libraries with ILM's own Caricature and I Sculpt software. All three programs run on SGI workstations. "We use shape libraries rather than trying to create actual facial anatomy, because all these characters are so different from one another," Campbell says. "We're not working with real creatures. We have to understand them sculpturally, but not technically."

One of the oddest characters is Watto, a Tatooine junk dealer who owns Anakin's mother, the slave Shmi (actress Pernilla August). We meet Watto—and Anakin—after Qui-Gon, Obi-Wan, and Jar Jar slip off Naboo in a damaged spaceship. A search for parts on Tatooine leads them to Watto. With wings like a hummingbird, a huge stomach, and an elephant-like trunk covering the front of his face, Watto presented two big challenges for the animators: making him fly and making him talk. "He looks like something that wouldn't work in the real world," says Tim Harrington, an animator who worked on both Watto and Boss Nass. To make him talk, they decided to have him use the left side of his mouth. "We had Rob [Coleman] do poses and we took Polaroids of him, and that's what the modelers used to model his mouth shapes," says Harrington. The animators used his shoulders to motivate his movement, tilting his wings accordingly. When Watto is hovering, his feet dangle beneath him.

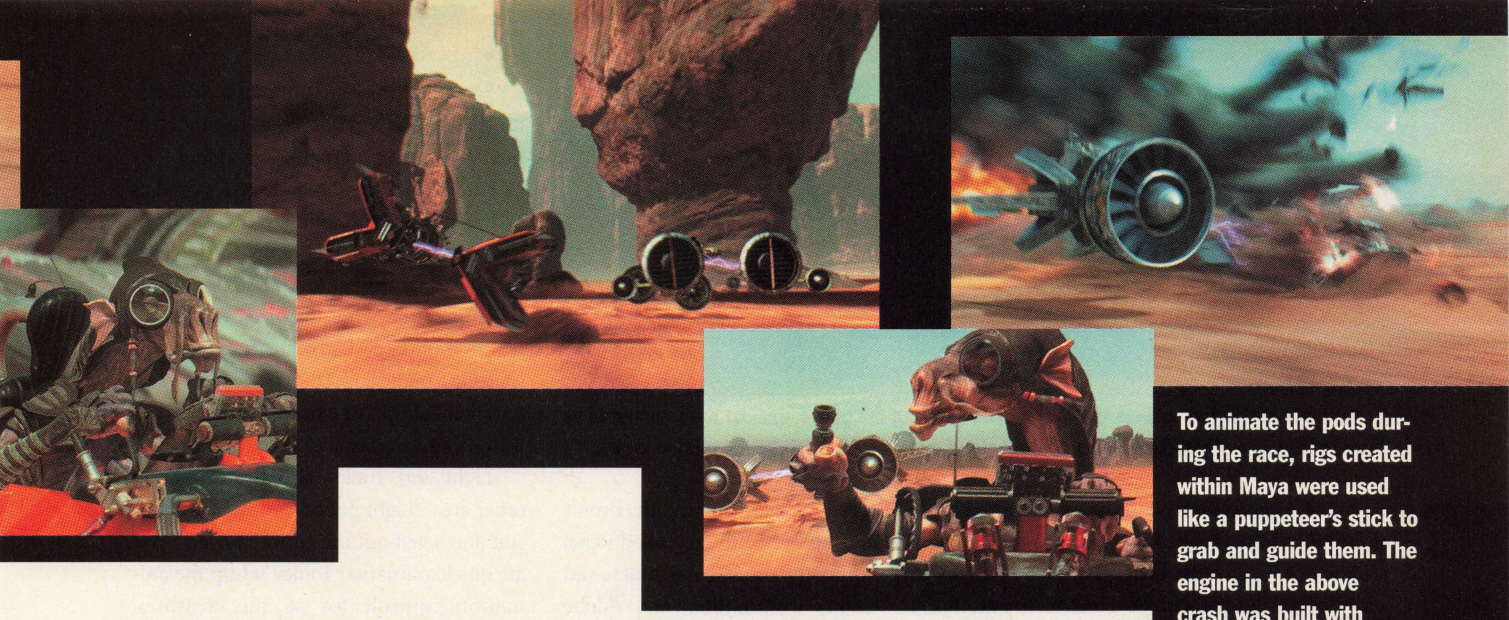
The wings themselves were animated using cycles. CG supervisor Smythe explains that animators would create several cycles of flapping wings, then TDs would render each separately with motion blur in Pixar's RenderMan and blend them with the body. To create Watto's "five o'clock shadow," the TDs used a fur renderer with multiple shadow passes; to animate the phone cord, they used the same type of simulation as they used for the cloth. Because the simulator must begin its interpolation before the first frame of the shot, Smythe's group created scripts to help the animators generate "pre-roll" animation.

Pod Racing

The fourth main digital character, Sebulba, is a Tatooine master pod racer. Pods are complex racing machines—two engines and a cockpit connected by ropes—that travel up to 600 mph over the desert terrain. On the ground, they're models. In the race, they're CG. Sebulba, however, is always CG. When he's not in a pod, he walks on his forearms and uses his feet like hands, which looks bizarre, but when he's in the pod, having an extra set of hands helps him do nasty things to his competitors. "He cheats a lot," says Patrick Bonneu, who helped animate him. "He tries to win at all costs." To animate his face during the pod



This hangar is all CG, as are the droids, whose motion is created with shot-specific motion-capture data. The only practical element is the fire.



To animate the pods during the race, rigs created within Maya were used like a puppeteer's stick to grab and guide them. The engine in the above crash was built with 12,000 pieces so that the dynamic simulator would have plenty to work with.

race to create an illusion of great speed, the Sebulba animation team used Caricature to move his skin, mustache, and goggles as if they were being pushed by the wind. Many of the other pod racers are also digital, as is the two-headed announcer.

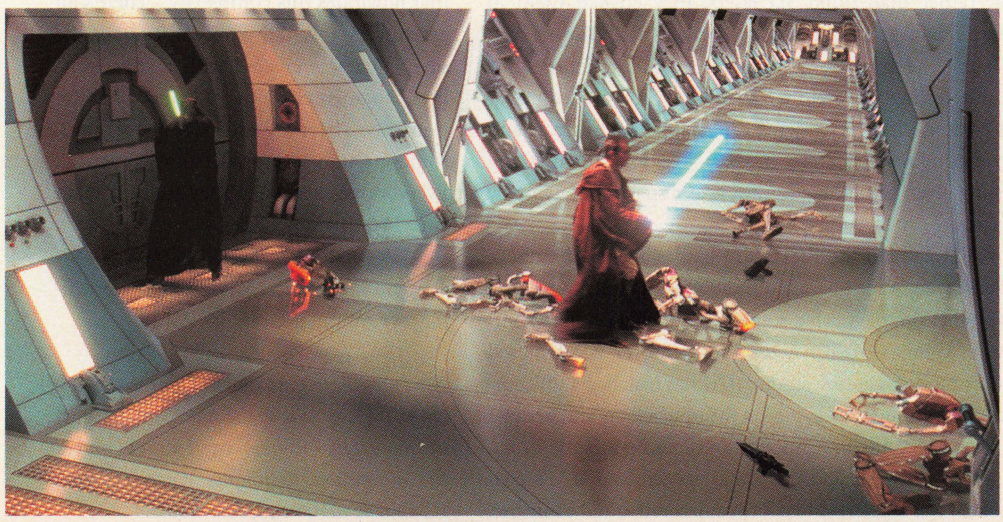
The pod race takes place in a huge stadium, which is actually a miniature set that the technical directors filled with digital people. Some of these people were captured with digital video, then cloned and turned into 150,000 sprites to occupy the stands; however, the 4000 to 5000 digital people milling around in front of the stands were modeled and then animated procedurally using a proprietary plug-in written by Hiromi Ono that runs inside Alias|Wavefront's Maya. "These digital people have freedom of will," says Habib Zargarpour, CG supervisor. "They avoid each other, they move in different directions; they can even decide to run to the bathroom."

To create the pod-race environment, the technical directors used digital matte paintings, CG models, and numerous texture maps. "We had a library of rocks, crags, and buttes," says Kevin Rafferty, lead CG supervisor. "To place textures on them quickly, we created a program that manages texture assignment." For the terrain, the R&D department created a program that would generate an adaptive optimized terrain on the fly for the miles needed during the 600 mph race. The task of compositing all these pieces was supervised by Tim Alexander, who worked with special software that compensated for the idiosyncrasies of the wide-angle lens used in the live-action shots. For example, he noticed that on the live-action plates, the color at the edges around people and objects split the red and blue, so he added that aberration to the CG characters. All the CG elements were rendered in sharp focus; the compositors added film grain, rack focus, and depth of field.

ILM devoted between eight and ten 32-processor Origin 2000s, each with between eight and 12GB of memory; two 16-processor, R10K Power Challenge machines; and four 256-MHz Challenges from its large render farm to this movie; all the machines are from SGI. "And then everybody's O2 turns into a render farm at night," Rafferty says. That effectively added another 200 machines, the SGI O2s used by the artists, TDs, and animators working on *Episode I,* to the render farm.

Work on the movie was divided among three visual-effects units. Rafferty had the task of overseeing all the CG supervisors on these units. "I helped make sure the foundation was sound, that the R&D came together, and that the new software and scripts being written on each unit were put into the pipeline," he says. At the peak of production, he was working with 78 technical directors, 25 compositors, and six associate technical directors. The latter were a kind of "hit team" that would help out wherever needed.

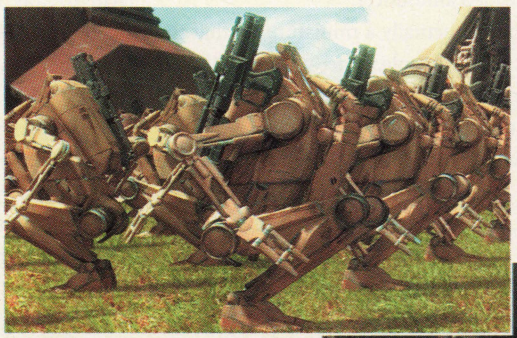
The visual effects supervisor for the cut-throat pod race sequences on Tatooine was John Knoll; Scott Squires' unit worked on sequences set in Coruscant. Dennis Muren's unit created the two big Naboo sequences: The underwater scenes—during which Qui-Gon, Obi-Wan, and Jar Jar trav-

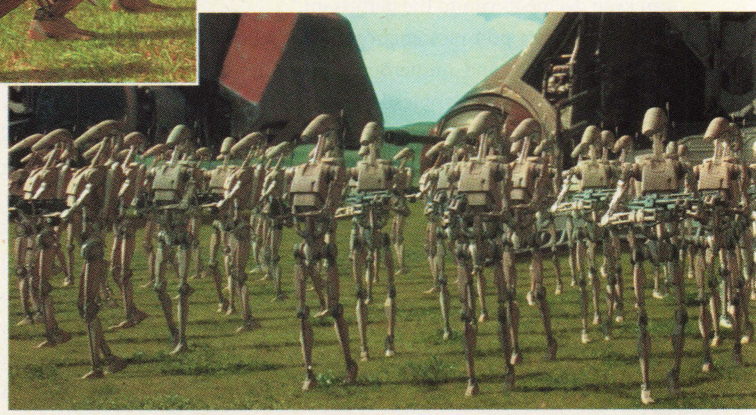


When a Jedi Knight's lightsaber slices through a droid, the droid's parts crash to the ground and bounce according to the laws of physics, as encoded into a dynamics program written specifically for droid fight scenes.

Although most of the Gungan soldiers in the front row (holding the power shields) were animated by hand, those behind were choreographed with the help of motion-capture data and motion cycles.

el to the Gungan cities—and the huge ground battle between the Gungans and the droids at the end of the movie. In addition to the pod race, Knoll supervised the so-called Rebel unit, a close-knit team that used tools such as Power Animator on SGI machines, and auto•des•sys' FormZ, Play's Electric Image, Puffin Design's Commotion, and Adobe Systems' Photoshop and After Effects running on Macintoshes, to create and animate the space-battle scenes. "Our group works outside the pipeline," says Stu Mashwitz, space-battle sequence supervisor. "We like to have one person do the modeling, lighting, and compositing for an entire shot. It wouldn't work for character animation, but it works for spaceships."





To unfold the battle droids, the animators used keyframe techniques, but to march the droids into battle, they relied more on motion-capture data.

The Battles

The space battle is waged by Naboo Starfighters, yellow, hot-rod like ships, that attack the Federation battleship, a fortress in orbit above Naboo. The battleship is a motion-control miniature; the Naboo Starfighters were created by Mashwitz and his team, whose aesthetic challenge was to make the battle look like a *Star Wars* battle. "No one has seen a space battle, but everyone knows what it's supposed to look like," Mashwitz says. "It's supposed to look like *Star Wars*." So rather than put lights at infinity, they set lights as if they were working on a motion-control stage (as in the first *Star Wars* movies). Similarly, rather than build 3D lasers, they created them in AfterEffects. For the big battles, they put background images on sprite cards. "One big card could hold a whole pre-rendered battle," he says. "Sometimes they're 2D, sometimes 3D. We'd do what worked for the shot." Interestingly, rather than follow a typical procedure for CG animation in which the look is created with the renderer, this group likes to create and control the look in AfterEffects by mixing several render passes. "We don't do anything straight out of a 3D program. Nothing. Even something as simple as a space ship flying by takes two or three composites," Mashwitz says.

While the Naboo Starfighters wage war with the Federation battleship in orbit above Naboo, on the ground, a huge battle is being waged between thousands of Gungan soldiers and Federation battle droids. Hero animation for this big scene was done by keyframe animators. Animation for the hundreds of Gungan soldiers and droids, however, was achieved with the help of motion capture. In its motion-capture studio, ILM has installed a 20-camera, Vicon8 system. Jeff Light, motion control supervisor, put on the optical dots and became a Gungan soldier. James Tooley, a technical animation supervisor, became a battle droid. Their motion was captured using Vicon software, and that data was fed into ILM's own MOJO motion-editing software, where it was converted to a form animators could easily use.

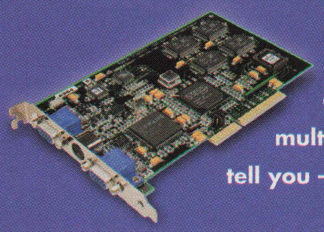
"By the time an animator sees the motion data, it looks as if it were handed to them by another animator," says Light. The captured motions were polished, stored as cycles, and used to animate thousands of characters. The choreography was created in Maya, according to Christophe Hery, CG supervisor, who organized the library of 143 motion cycles by creature types. To speed the rendering, Hery developed a system that cut the time from 13 minutes per frame to 3 seconds.

Light and Tooley also helped out in other areas. Light put on a motion-capture suit and acted out the entire movie to create quick animatics; Tooley set up the animation controls for all the creatures. "Some of the most complex animation controls were on the destroyer droids, because these droids compress into a wheel and accurately roll," he says.

In this movie, it seems the deeper you investigate, the more detail you can find, not only visual details, but in techniques for creating complex scenes more efficiently. Or, more to the point: "More, better, faster," says Rafferty, who describes a scene that illustrates this complexity. "There's an exterior establishing shot of Naboo," he says, "that was created with matte paintings, augmented with CG and practical elements. There are little CG people in it, some motion captured, some practical. Everybody gasps when they see it. It takes your breath away."

Barbara Robertson is West Coast senior editor for Computer Graphics World.

Next month, in Part II of our Star Wars *coverage, we look at how the effects crew created the models for animators and for sets, and at the animation techniques emerging from ILM's new motion-capture studio.*



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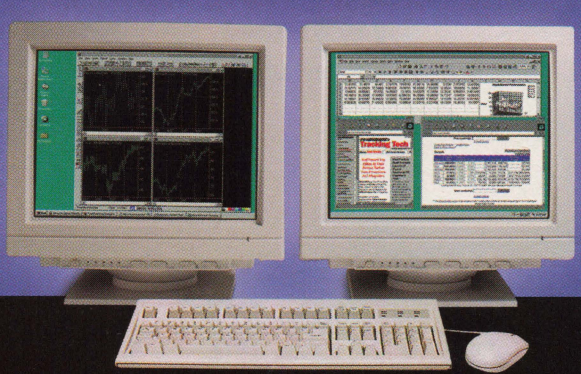

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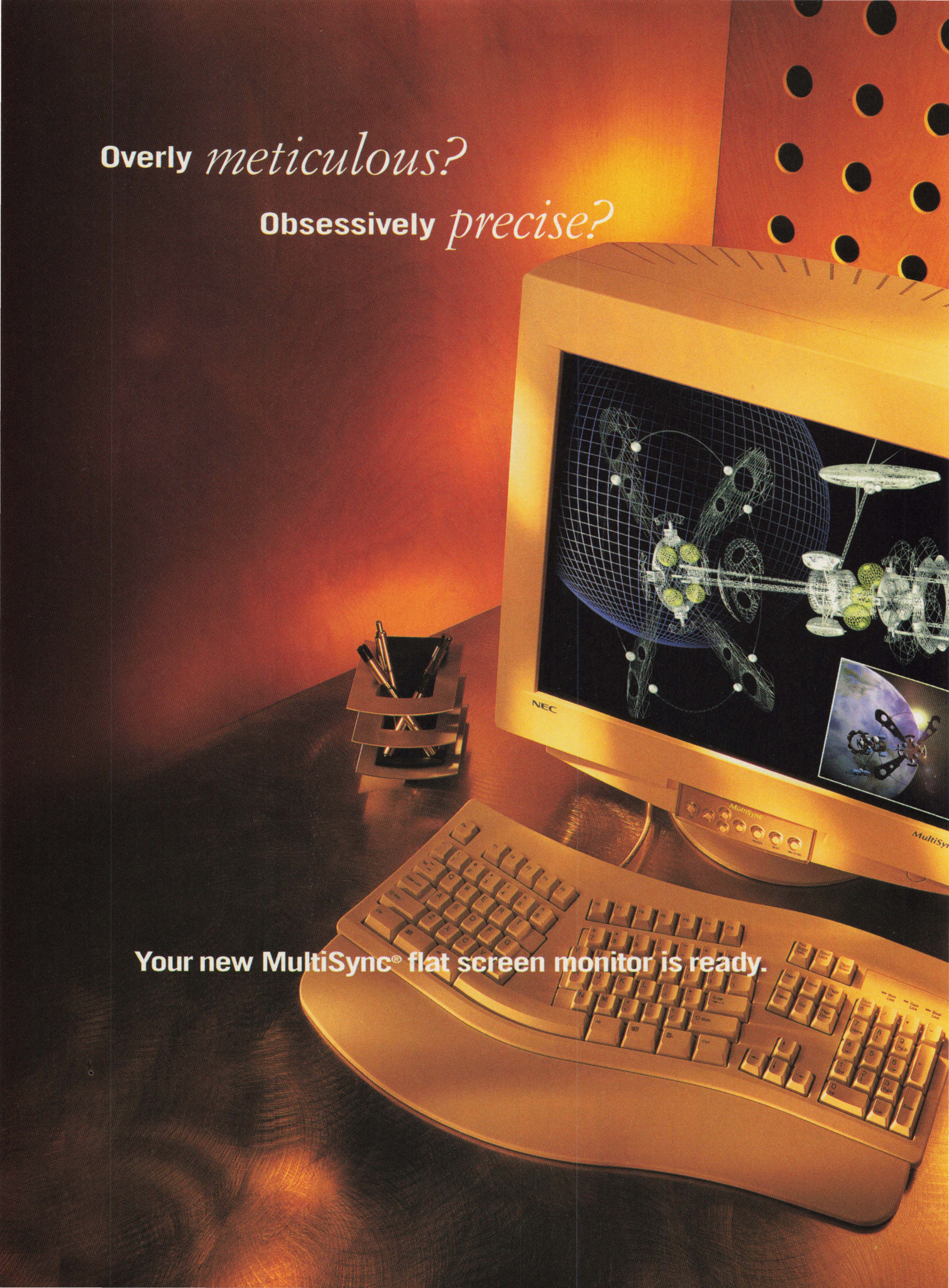
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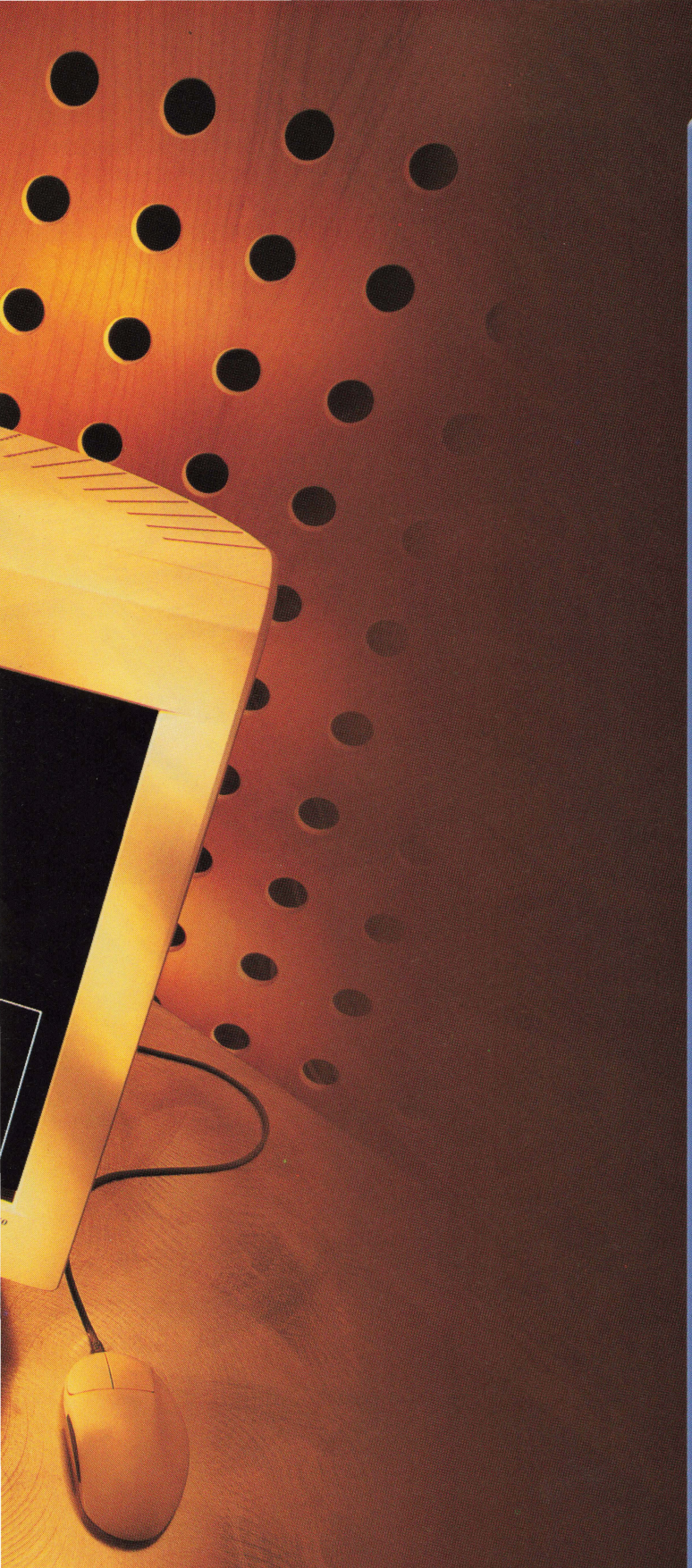

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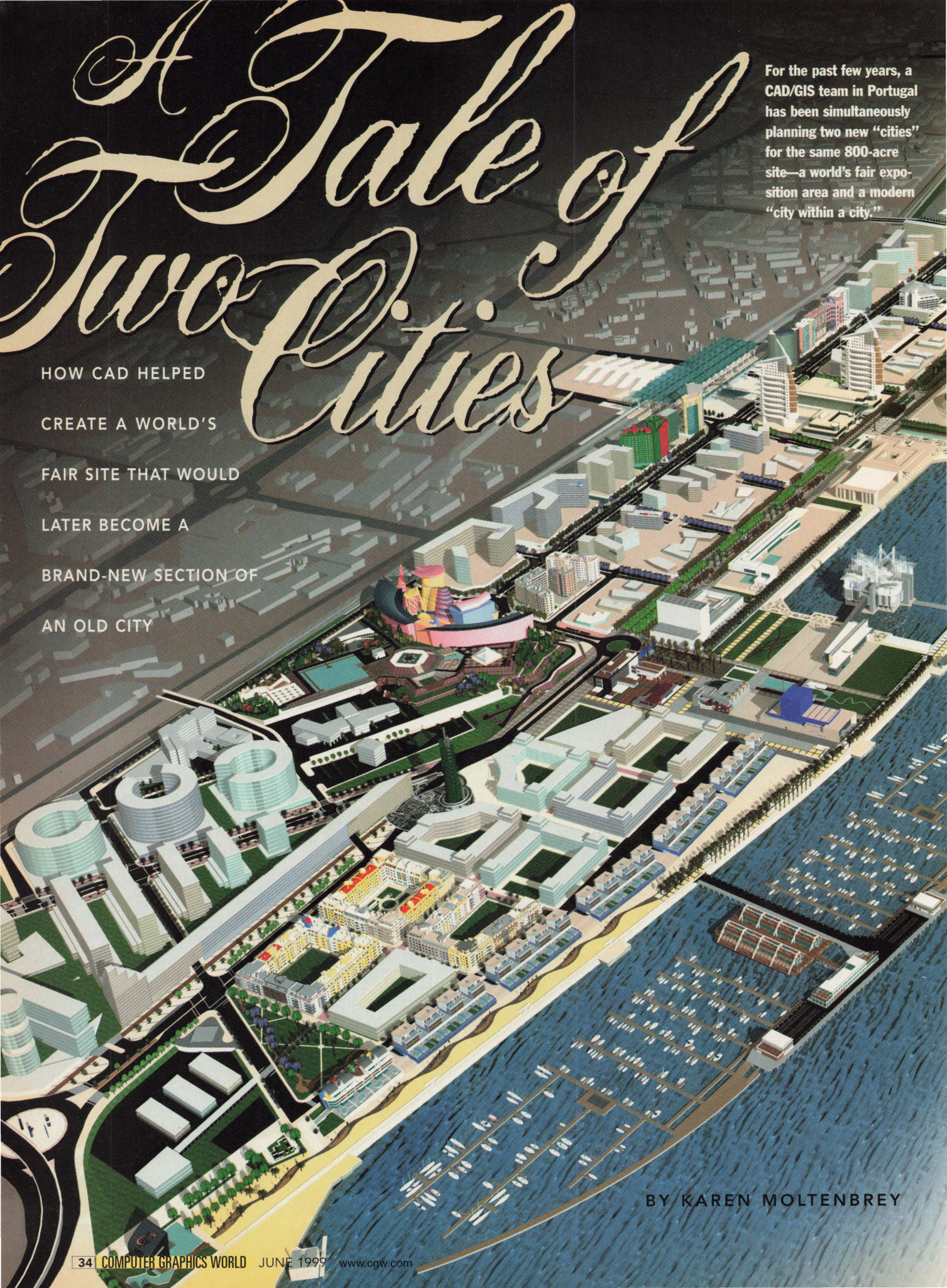
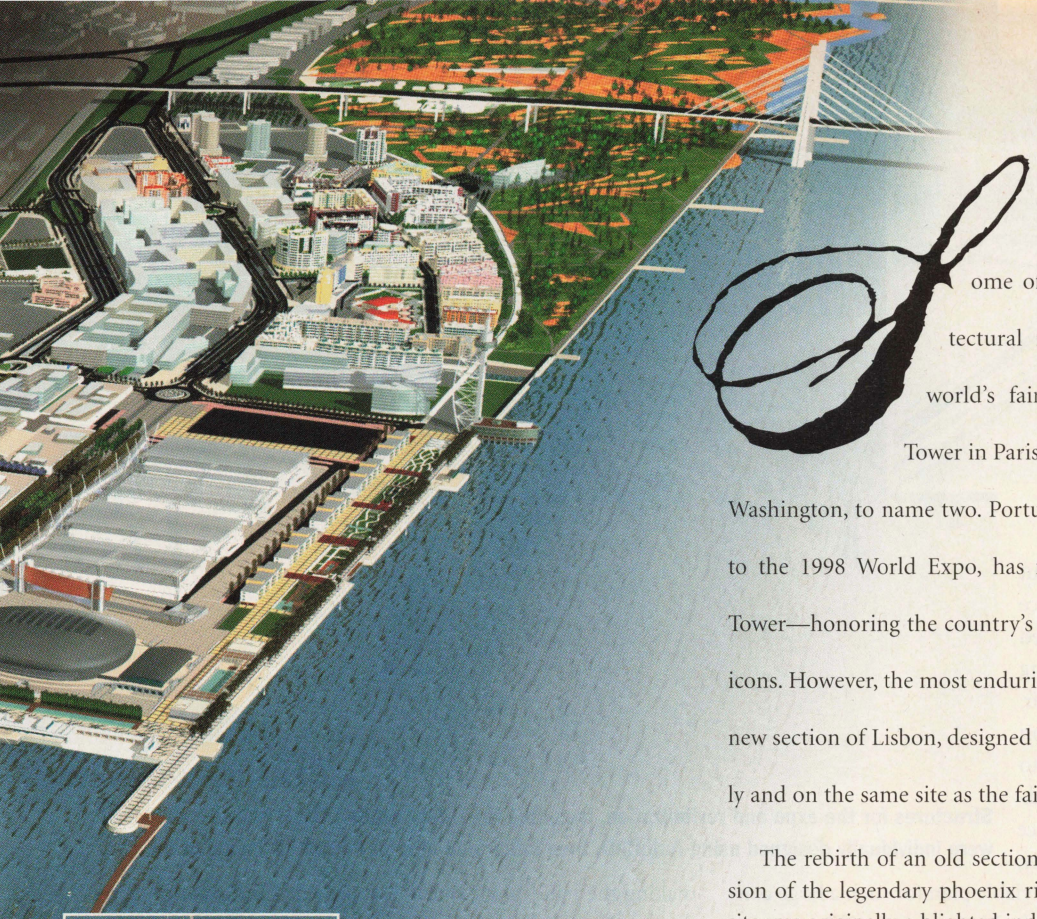
A Tale of Two Cities

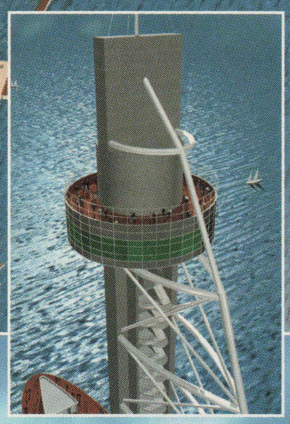
For the past few years, a CAD/GIS team in Portugal has been simultaneously planning two new "cities" for the same 800-acre site—a world's fair exposition area and a modern "city within a city."

HOW CAD HELPED CREATE A WORLD'S FAIR SITE THAT WOULD LATER BECOME A BRAND-NEW SECTION OF AN OLD CITY

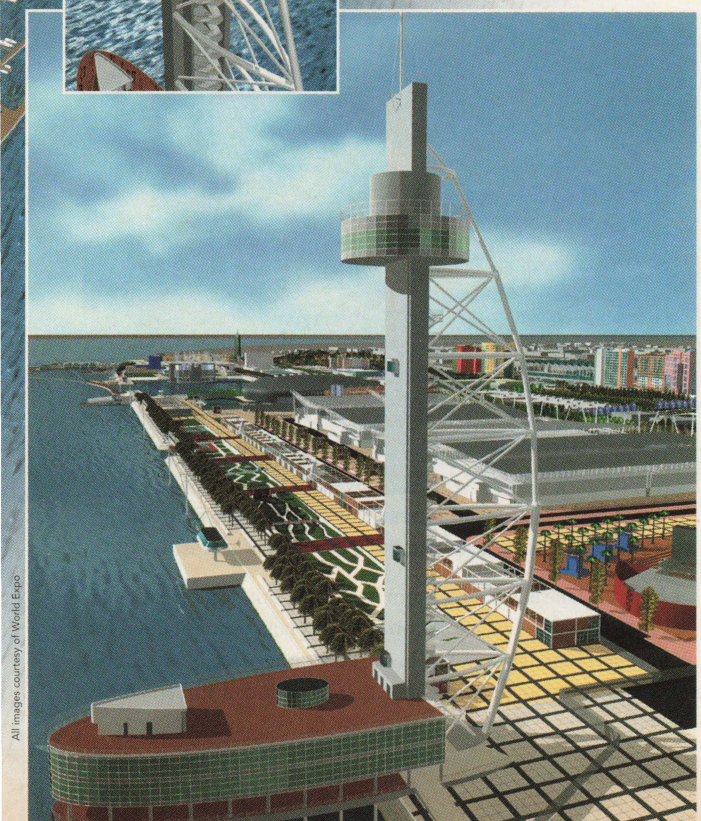


BY KAREN MOLTENBREY





Like many other World Expo host cities, Lisbon constructed an architectural monument commemorating the event. The Vasco da Gama tower, honoring the country's famous explorer, was the fair's main attraction, providing visitors with a view of the expo site from the observation deck (inset).



All images courtesy of World Expo

Some of today's most endearing architectural monuments are testaments to world's fairs gone by, such as the Eiffel Tower in Paris and the Space Needle in Seattle, Washington, to name two. Portugal's capital city of Lisbon, host to the 1998 World Expo, has now added its Vasco da Gama Tower—honoring the country's famous explorer—to that list of icons. However, the most enduring legacy from Expo 98 will be a new section of Lisbon, designed from the ground up concurrently and on the same site as the fair using CAD technology.

The rebirth of an old section of Lisbon is a modern-day version of the legendary phoenix rising from the ashes. Indeed, the site was originally a blighted industrial area littered with military and industrial waste from a past era. But the project entailed far more than reclamation and reconstruction. An equally daunting challenge was to design this new "city within a city" so that it would first accommodate "countries within a country" for the fair.

"The World Expo was the pretext for this entire [urban development project]," says Jose da Conceicao Silva, CAD/GIS manager for World Expo, the organization responsible for developing and managing the Lisbon site. "It permitted a zone that was completely degraded to be restored. I think it was a great opportunity to build a new city fabric in this space."

When completed in 2010, the urban revitalization project, officially called Parques das Nacoes (Nations Park), will boast about 12.5 million square feet of residential development that will provide living space to about 25,000 residents; 5 million square feet of office space where about 18,000 employees will work; 1.5 million square feet of retail shopping; about 250 acres of parks and open space; new schools; and a hospital. But building so much new infrastructure and development during a short period of time, in a city with an 800-year history, requires detailed planning—which was accomplished with Autodesk's (San Rafael, CA) AutoCAD and Kinetix's (San Francisco) 3D Studio software.

According to Conceicao Silva, there was no question, even from the outset, that computer technology would hold the key to the project's success, especially given the fact that an entire section of the city was being planned and constructed from bare earth. "All the state-of-the-art infrastructure [such as the utilities, water and waste systems, and roads] had to be laid out from the ground up. It would have been next to impossible to accomplish this without using 3D technology," he says. "Time was also crucial. The technology helped us use our time more efficiently and make critical decisions more quickly."

Structures for the expo and revitalization, including the Orient Station (inset shows a top view) were individually designed using AutoCAD, then integrated into an overall 3D model of the site.

Planners with Vision

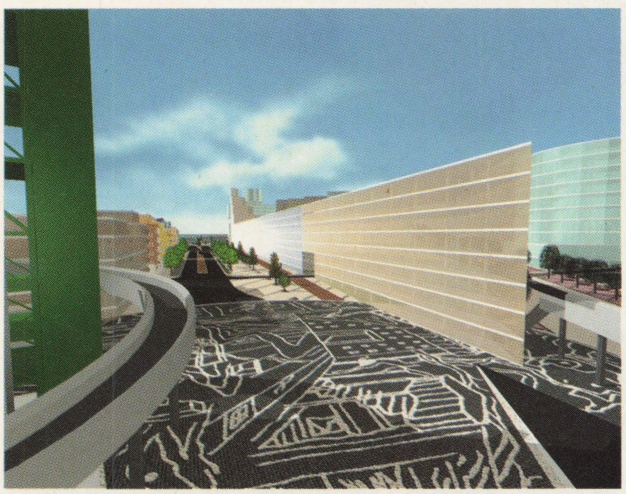
The project was conceived about six years ago, when one of the vice presidents of the Expo suggested that the city enter the bidding competition to host the 1998 fair. His plan called for the conversion of an unused part of Lisbon into the 800 acres of open space needed for the various exhibits. Once the bid was awarded to the city, the next step was to formulate a viable plan for such a large conversion. "The [Expo committee] had a very interesting, economical approach to the project," says Jorge Horta, manager for Autodesk, Portugal. "In Seville, Spain, which hosted the previous exposition, all the financing was through ticket sales, company sponsorships, and government aid. In Portugal, the [committee and government officials] decided to do a live economical program that would be financed in time by real business, not spot business [generated during the four months of the fair]. As a result, they decided to make a new, very modern part of Lisbon that would exist long into the future."

That decision drove the planning for the entire event. First, the site had to be prepared, which was the point at which computer graphics technology was introduced into the process. The planners began with an aerial photograph of the site, which was digitized into Autodesk DWG format, then converted into a 3D AutoCAD file that served as the base for the site plan. The team also incorporated new, related improvements into the site plan, such as the Vasco da Gama Bridge, a highway that creates a semicircle around the city, and the transportation center situated on the perimeter of the area.

Because the site involved extensive terrain remolding, it had to undergo comprehensive land analysis, which was performed using Landsoft's (Kuala Lumpur, Malaysia) LandCAD, a 3D landscape plug-in for AutoCAD. Then, using Kinetix's 3D Studio, the group constructed a 3D virtual model of the area, which provided a clearer vision of what would lie ahead. "We began with a simple visualization that permitted us to conceptualize—with much greater clarity than a feasibility study, which essentially provides only numbers—the amount of earth that would have to be moved for specific situations in this project," says Manuel Jose Silva, a visualization team leader for World Expo.

Adds Conceicao Silva: "Not only did the CAD model help in making the [site] plots, but it also provided information about the topology, allowing us to simulate the earth clearing. So right from the beginning, the whole design was done on the computer. There were practically no drawings on paper, which is amazing for a project of this scope."

The initial 3D virtual model also helped the group sell the Expo to exhibitors and investors at a time when the project was still just a vision. "We had to sell some people on a concept that would take nearly two decades to complete," says Conceicao Silva. Additionally, the project imagery had to be disseminated nationally and internationally to potential exhibitors and those wishing to stake a building claim in the ultramodern urban area.



Planners used 3D Studio to tweak this pavement design, which uses colored rocks to simulate the movement of waves.

After the site was cleared, two sets of plans were required for all new permanent structures in the area—those for Expo exhibitions and subsequent users once the event ended in September

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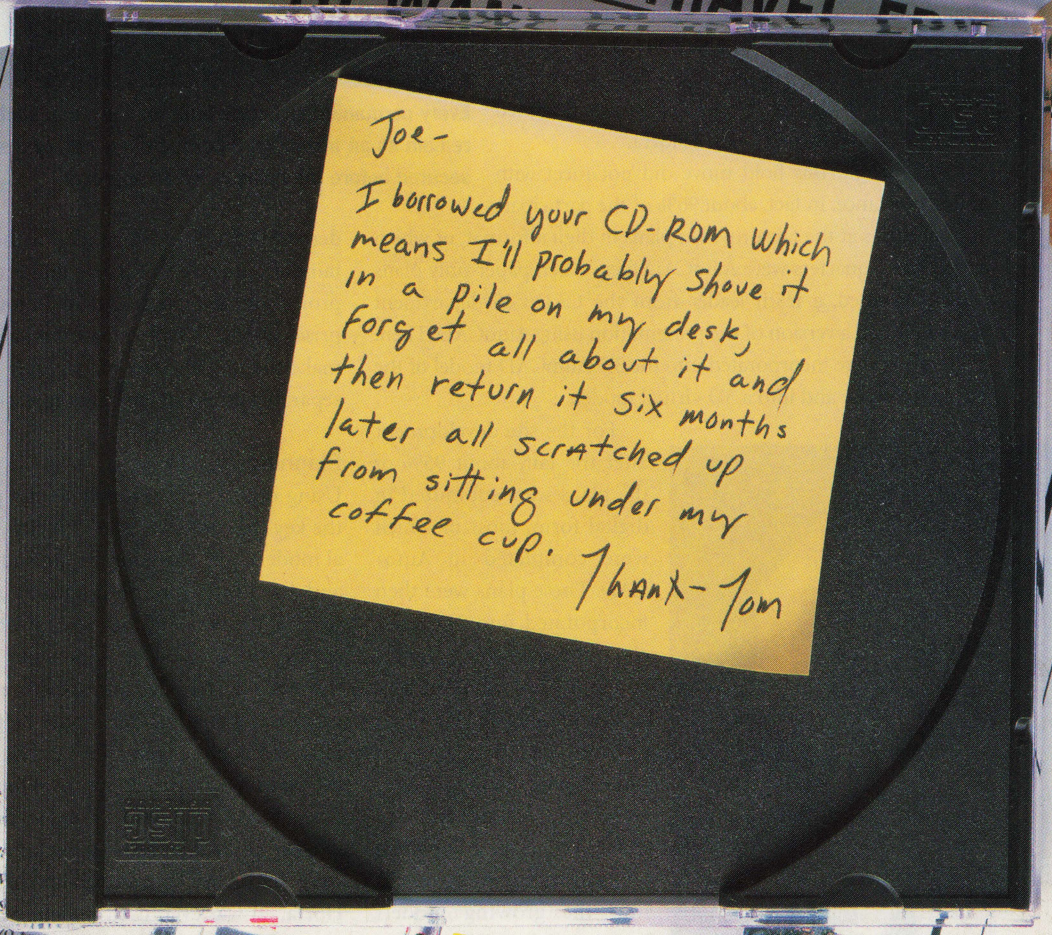

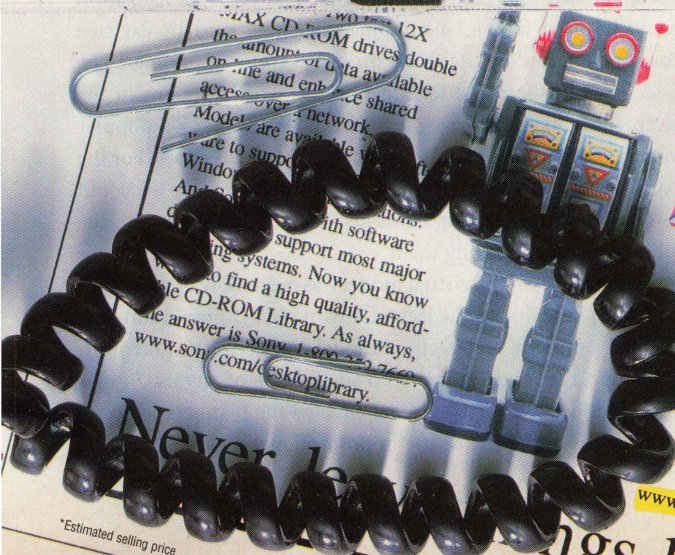

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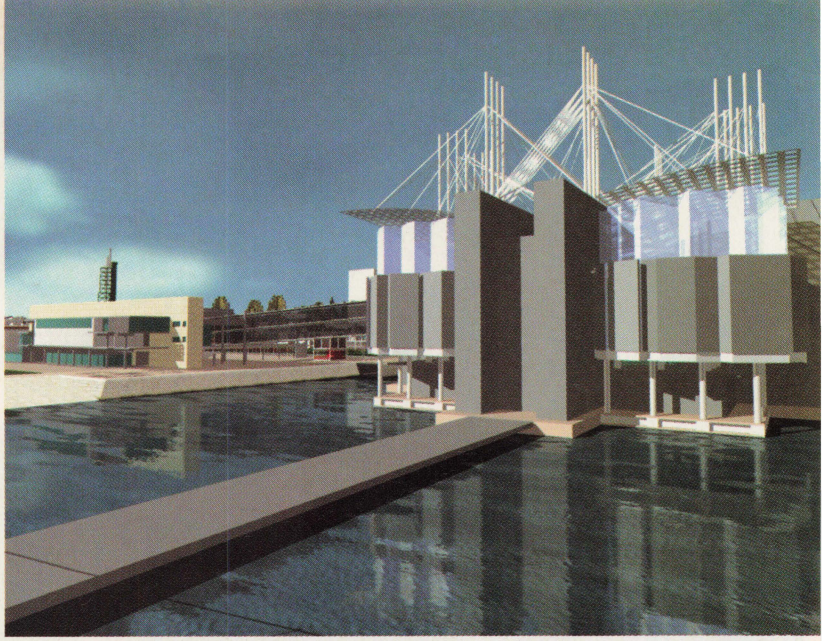
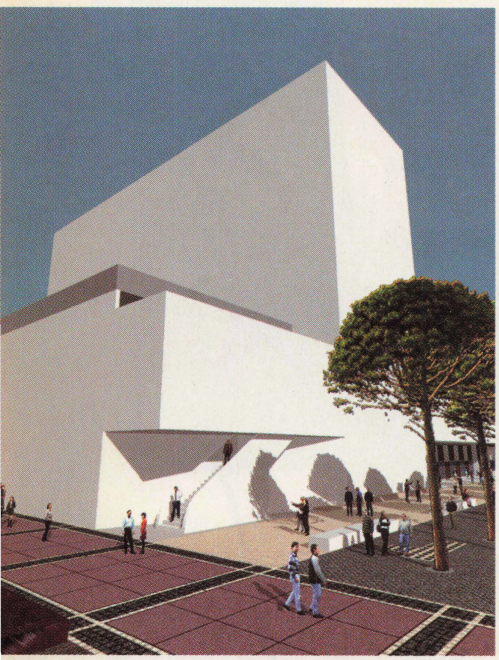
1998. These included the Oceanarium, Portugal Pavilion (turned into the Ministers' Council building), the Lisbon Exposition Center, and several hotel and apartment complexes. Other exhibits had to be temporary structures that were completely recyclable in terms of materials as well as usage. "Using all the old waste material was very important—even the concrete used in [both phases] consists of the stone and debris from the buildings that were torn down during the initial cleanup," says Horta.

So when the planners began building a database of graphical information for the projects, they made a courageous decision: They requested that any architectural plan submitted be accompanied by a digital file, preferably in AutoCAD format, since the model base was built using that software. "This may not be so unusual now, but it was five or six years ago, making it the first World Expo to be designed totally in digital format," notes Horta.



Every permanent structure built for the expo, such as the Oceanarium, had to remain as an attraction following the event, or a secondary use had to be secured before the plans received approval.

Surprisingly, this bold move did not meet with much resistance. In fact, about 90% of the participating countries at the fair provided plans in digital format, of which about three-quarters were AutoCAD files. When paper-only plans were submitted, a team leader from the CAD/GIS department would rebuild a version of the presentation using AutoCAD. Then, these plans were incorporated into the 3D AutoCAD model of the entire Expo site and into a 3D virtual model.



Every proposed building was created as a basic 3D element, then placed into a master model to ensure that it fit into the overall scheme. Once approved, a more detailed element was incorporated.

For the site development after the fair, about 95% of the plans were submitted in digital form, most of which were completed in AutoCAD. These plans were then incorporated into 3D models of the site, which already contained the infrastructure data from the fair. "We started with basic data, but our models grew as the new releases of [3D Studio and AutoCAD] came out, which let us introduce more details into the growing models because of the advanced feature sets in the software," says Alexandre Rocha, a project leader in the CAD/GIS department at World Expo.

At first, the CAD group placed volume representations of the buildings in its model, gradually replacing those with more detailed renderings as the project began to gel. "Then we added as many details as possible to get the best visual representation. This was done for both the urban site and the exposition site," Rocha says. Currently, the fully rendered 3D Studio Max model of the urban renewal phase contains about 300MB of data—and is constantly expanding as new projects are accepted. The 3D AutoCAD wireframe model comprises about 135MB of data and about a million 3D facets. To make the model more manageable and easier to load, the team separated it into six models, representing six development zones.

Planning Ahead

Using digital data throughout the project phases proved to be the key that unlocked the new city of Lisbon. In all, three virtual models were used: for the groundwork phase, the Expo phase, and the post-Expo, or urbanization, phase. From the outset, using a 3D model of the groundwork provided a means of estimating the amount of work—and costs—involved in readying the site for the new infrastructure and development. Later, a more developed virtual model helped in the decision-making process, enabling the various public boards to properly visualize the plans needing their approval for both projects.

As that virtual model grew, so did its role. "Everyone started looking at it differently—what kind of impact would a building color here have or a design in the pavement there have," says Horta. "It was even used to determine what types of vegetation would be used in the landscaping, and how a particular tree would be affected by the shade projected from a building." The model was further used to integrate the artistic designs in the pavement made by colored, textured paving stones—a popular Portuguese method of landscaping. Adds Manuel Silva: "[For the Expo] the result was 100% what we wanted because we could visualize the entire setting—not just the buildings, but also the public space surrounding them."

The reliance on the virtual model was even more apparent for the Expo phase due to the lack of a working 3D physical model. "We had a physical architectural model, but because of the project's scope, the model proved too small to be of any use," notes Horta. Besides, the virtual model enabled the planners to create fly-throughs of the site to use in promotional materials, such as

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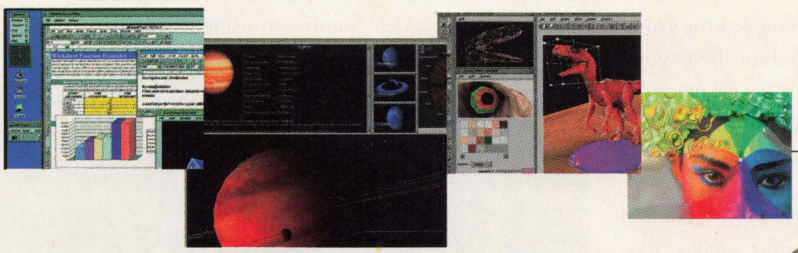

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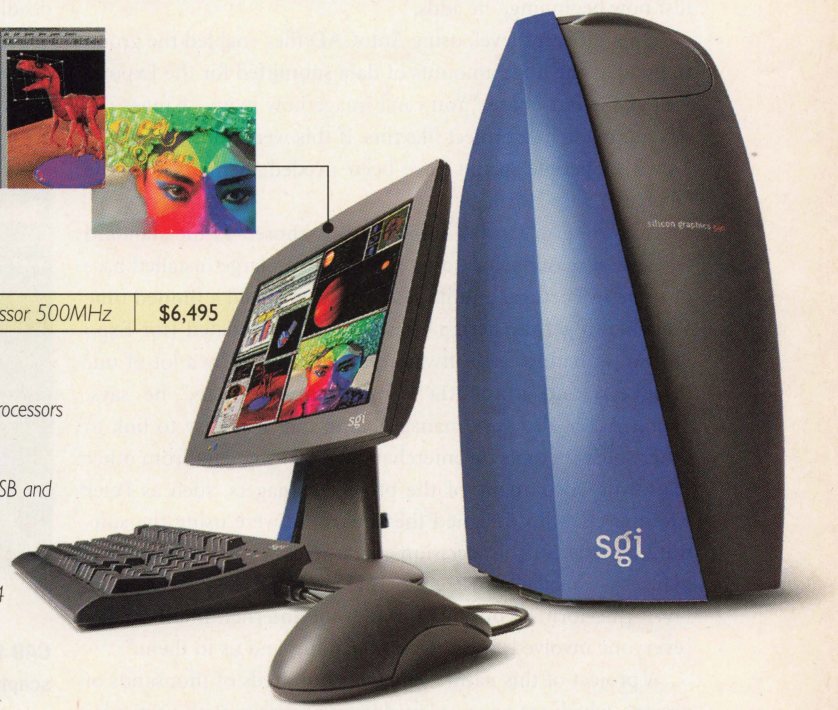

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The 3D model contains detailed images of all the permanent structures, such as the Outdoor Pavilion.

video animations for both the Expo and the revitalization. "The underlying goal was to sell the redevelopment of the urban area. The model enabled us to show a part of the city already built, when in reality, the construction is just now beginning," he adds.

On a different level, using AutoCAD files enabled the group to manage the huge amounts of data submitted for the Expo as well as the last phase. "You can't image how many changes per day are made in a project like this. If this were done by hand, a crowd of people would have been needed to manage [those changes]," says Horta.

According to Horta, AutoCAD was chosen as the standard for several reasons, including the software's large installed base of users in Portugal and its ease of use. "We had a limited time schedule to get the design phase ready and updated [for Expo 98], so we had to use software that was known by a lot of our designers, and AutoCAD is very popular here," he says. "AutoCAD is also very manageable in that it is easy to link to other software tools for interchanging drawing data from other platforms. Also, many of the project managers, such as Peter Chermayeff, who designed the aquarium, were using the software already, so this decision made it easier to update those plans by e-mail because AutoCAD makes it easy to produce DWF [file-format] outputs through the Internet. It also makes [everyone involved] more accessible to us, and us to them."

A project of this nature generates hundreds of thousands of designs, which are reviewed by dozens of groups with particular interests—landscape, construction, environmental impact, etc.—and each uses AutoCAD. To handle all that digital information, the CAD group initially used a Novell and Windows NT network to link about 50 Pentium PCs for data storage and modeling. "At the urbanization level, projects were constantly arriving for different areas: the urbanization, licensing, and construction, all on different servers," Conceicao Silva says. "In the [urbanization] phase, we have about 100 people in different buildings all looking at the AutoCAD designs and the images on the 3D models." More recently, the group migrated to more powerful Pentium II platforms, which enable them to perform their work (including the rendering) on only six machines.

Furthermore, all the AutoCAD and 3D Studio Max design information is now available on the group's intranet sites. This will enable an architectural firm, for instance, to obtain all the relevant information about the infrastructure so it can more easily and accurately integrate its designs with the master plan. "While the fully rendered models are the most exciting representations of the development, the volumes of knowledge regarding all aspects of the project are critical to our worldwide partners. By making this information available through the Web [using Autodesk's Whip! viewer plug-in], communication and collaboration is improved dramatically, making this city of the future a reality," says Conceicao Silva.

There were really only two deadlines for the project, according to Horta. The first one was in May 1998, when the fair opened; the second is in 2010, when the renewal phase is scheduled for completion.

"It's really amazing that this group was able to meet the first deadline without any major difficulty or financial loss," he says. "Portugal is not a rich country, so using technology in this way was [critical] in being able to accomplish all the necessary [construction and planning] that was required when hosting a world exposition. If the project wouldn't have been well planned and well managed, it would have been disastrous."

CAD technology was used in every design aspect, including landscaping, which was used to determine what vegetation to plant.

Karen Moltenbrey is an associate editor of Computer Graphics World.

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START YOUR ENGINES

LIKE COMMERCIAL ANIMATION SOFTWARE A DECADE AGO, NEW 3D GAME ENGINES FUEL A FAST-PACED INDUSTRY

BY BOB CRAMBLITT

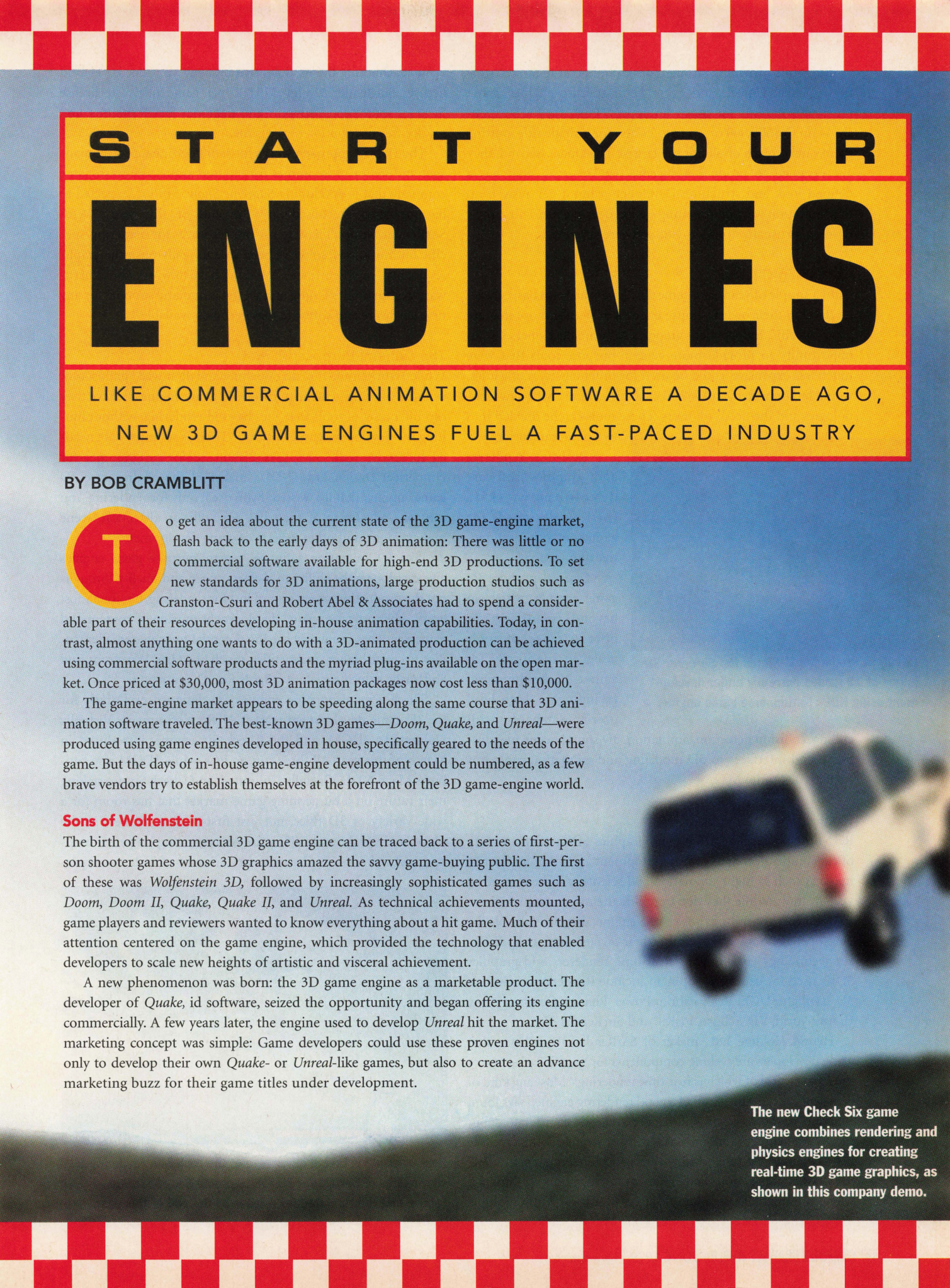
To get an idea about the current state of the 3D game-engine market, flash back to the early days of 3D animation: There was little or no commercial software available for high-end 3D productions. To set new standards for 3D animations, large production studios such as Cranston-Csuri and Robert Abel & Associates had to spend a considerable part of their resources developing in-house animation capabilities. Today, in contrast, almost anything one wants to do with a 3D-animated production can be achieved using commercial software products and the myriad plug-ins available on the open market. Once priced at $30,000, most 3D animation packages now cost less than $10,000.

The game-engine market appears to be speeding along the same course that 3D animation software traveled. The best-known 3D games—*Doom*, *Quake*, and *Unreal*—were produced using game engines developed in house, specifically geared to the needs of the game. But the days of in-house game-engine development could be numbered, as a few brave vendors try to establish themselves at the forefront of the 3D game-engine world.

Sons of Wolfenstein

The birth of the commercial 3D game engine can be traced back to a series of first-person shooter games whose 3D graphics amazed the savvy game-buying public. The first of these was *Wolfenstein 3D*, followed by increasingly sophisticated games such as *Doom*, *Doom II*, *Quake*, *Quake II*, and *Unreal*. As technical achievements mounted, game players and reviewers wanted to know everything about a hit game. Much of their attention centered on the game engine, which provided the technology that enabled developers to scale new heights of artistic and visceral achievement.

A new phenomenon was born: the 3D game engine as a marketable product. The developer of *Quake*, id software, seized the opportunity and began offering its engine commercially. A few years later, the engine used to develop *Unreal* hit the market. The marketing concept was simple: Game developers could use these proven engines not only to develop their own *Quake*- or *Unreal*-like games, but also to create an advance marketing buzz for their game titles under development.



The new Check Six game engine combines rendering and physics engines for creating real-time 3D game graphics, as shown in this company demo.

But while providing strong toolsets and great name recognition, Quake, Unreal, and other game-specific engines aren't practical solutions for most developers. First, they are expensive—up to $500,000 or more to license for a single title, putting them out of reach of all but the largest developers. Second, they are designed to produce a specific type of game that has a defined look and structure. Developers cannot get away from this limitation without rewriting a great deal of code. Third, their developers usually don't provide software support.

Expanding Choices

Until a couple of years ago, game developers had two basic choices: develop their own in-house engines or license those that are game-specific. Independent graphics software developers saw an opportunity to provide more general-purpose tools that were much less expensive, could be used for different styles of games, would be supported, and would evolve in concert with new technologies and the needs of users. These tools can be divided into two basic categories:

Headfirst Productions' *Simon the Sorcerer 3D* is one of 19 games currently under development using NDL's NetImmerse game engine.

- Real-time renderers and graphics software development kits (SDKs) designed for games and other interactive applications.
- General-purpose 3D game engines, which go beyond rendering to offer a range of tools designed specifically for game development, including high-level object databases with culling, collision detection, animation, 3D sound, scene management, and interfaces to 3D modeling and animation programs such as 3D Studio Max.

Piecing Together a Solution

Real-time rendering software and graphics SDKs offer a variety of capabilities geared to game development and other interactive markets such as flight simulation and scientific and engineering visualization. While they don't provide the more comprehensive solution of a general-purpose game engine, they are valuable for developers who want to assemble their own engines using different technology components. Real-time renderers and graphics SDKs used for game development include RenderWare, Genesis 3D, Twilight3DGE, Realimation, Power Render, Geometry Box II, AnyWorld, VD/Eclipse, VisKit, and SurRender 3D.

Hybrid Holding Ltd., maker of SurRender 3D, believes that game developers are seeking components for specific tasks, one of the most critical of which is real-time rendering. "Most any kind of game engine can run on top of a good rendering engine," says Jouni Mannonen, the company's developer relations coordinator, "but most game engines that are created from scratch do not include half the rendering functionality of a good rendering engine. The industry is going more and more toward component thinking, where you might license multiple pieces of software from multiple vendors, choosing the modules that best suit your needs." Hybrid licenses SurRender 3D for $75,000 per game title. The license includes source code, support and upgrades for 18 months, and royalty-free distribution of the game.

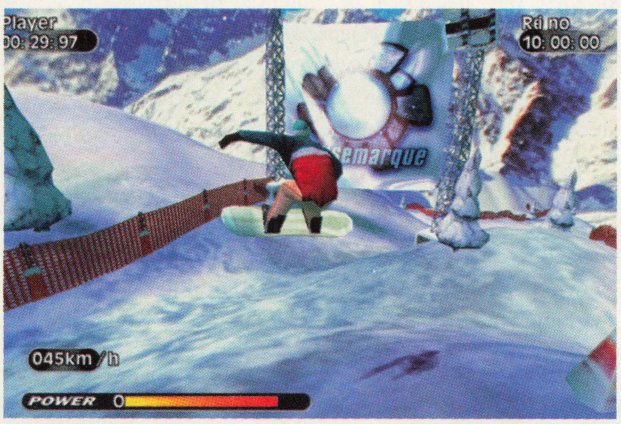
The Hybrid approach works for Jani Penttinen, project manager and senior programmer for Housemarque, a Finnish game company that is developing *Supreme Snowboarding*, expected to be published worldwide by the end of this year. "With SurRender, we don't have to use our resources for rendering-specific optimizations, so we've been able to really push the graphics quality," says Penttinen. "We don't have to worry about hardware-compatibility issues, and we get automatic support for any new hardware and software that becomes available."

The General-Purpose Market

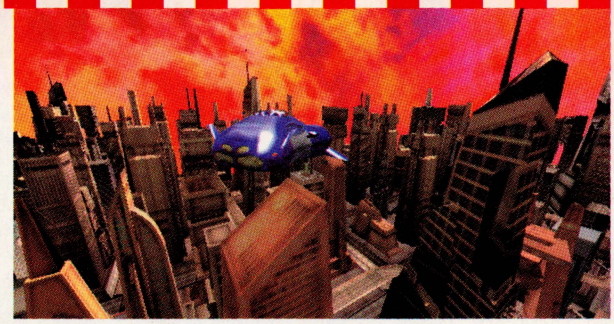
While Hybrid touts the "do one thing and do it well" philosophy, vendors offering general-purpose 3D game engines believe they can offer a set of tools that goes beyond rendering, without limiting the developer's game options. "There is so much data needed to render well," says Lars Bishop, senior programmer for Numerical Design Ltd. (NDL), maker of the NetImmerse 3D game engine, "that it's wasted if you use it only for rendering. You can take advantage of that data for collision detection, scene management, and other aspects of game development."

Like 3D animation software, general-purpose game engines give developers the ability to increase speed and quality throughout the production process—not just for rendering, but for almost every other aspect of game development outside of content and gameplay. These engines have the potential to enable smaller studios to create higher-quality titles, much like Alias, Wavefront, and SoftImage helped elevate standards for 3D animation.

Three general-purpose engines are designed exclusively for the 3D game-development market: NDL's NetImmerse, Virtually Unlimited's 3DGM, and the Check Six engine, introduced in March of this year. All three run on PCs, while 3DGM also supports Macs. NDL, Virtually Unlimited, and Check Six are staking their future on a burgeoning game market that has room for a wide variety of 3D titles, not just first-person shooters in the *Doom* and *Quake* mold. They are concentrating on game developers who don't have the necessary amount of in-house exper-



Housemarque is taking advantage of the real-time rendering capabilities of SurRender 3D for *Supreme Snowboarding* (above and right), slated for release by the end of this year.



***Rocket Police*, a flying-car game that takes place in a futuristic city, is currently being developed by Cosmic Cube using Virtually Unlimited's 3DGM game engine.**

tise for high-level 3D programming or those who want to devote their resources to creating content, rather than internal software engineering.

"For many developers, it's a question of time-to-market and how to use internal resources," says John Austin, NDL's president. "These developers might have the programmers in house to do 3D titles, but they want to do it faster. They want the flexibility to do titles that incorporate different styles. For them, a general-purpose 3D game engine is a good alternative to in-house engineering."

Peter Laufenberg, CEO of Virtually Unlimited, says the game market's huge growth and increasing number of new development companies has created a need for general-purpose 3D game engines. Many of the new developers do not have in-house programming resources to create sophisticated 3D games and bring them to market quickly. "The complexity of the games has been increasing," says Laufenberg, "so these new companies as well as existing ones are seeking off-the-shelf solutions."

Joe Enzminger, president of Check Six Studios, says developers are looking at these products because of the cost of R&D. "They're finding that it is costly to keep on that leading edge, especially when hardware technology is moving so quickly. The smart companies are finding that if they can buy the technology, they can focus their resources on developing hit-level content."

Building a Brand Name

The challenge for vendors of general-purpose 3D game engines is to establish brand-name recognition in the marketplace. None of the general-purpose engines have Quake or Unreal's built-in advantage of sharing a name with a best-selling game. And as with 3D animation software, it is difficult to distinguish between the packages based on features alone.

NDL, Virtually Unlimited, and Check Six all concentrate on what could be called "faster, better, and compatible" technologies: features such as database culling and continuous level of detail that increase speed while maintaining quality, image-enhancing features such as multiple texture and lighting effects, and connectivity to other products and technologies used commonly in game development. NDL emphasizes a comprehensive feature set that supports multiple game types. Virtually Unlimited stresses fast software rendering, polygon-precise collision detection, and support for PCs and Macs. Check Six focuses on its visual features, a physics engine, and ease of managing content.

All three vendors recognize the need to sell not just a product, but a partnership, providing support, maintenance, and the promise of ongoing technology development to meet customers' needs. This echoes the early days of 3D animation software,

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when a high level of support was needed for studios dipping into the digital waters for the first time.

The advanced features of game-engine software, the support, and the non-stop R&D required to stay abreast of hardware developments come at a price that is also reminiscent of early 3D animation software: 3D engines range from around $30,000 to $100,000, depending on factors such as whether the vendor offers source code and the number of titles for which the software is used. These costs, say vendors and customers, are more than justified by the ability to bring graphically rich, realistically animated 3D games to market faster and at a lower cost.

Red Orb Entertainment's *Prince of Persia 3D*, being developed with NDL'sNetImmerse game engine, is part of the migration of popular titles from 2D to 3D.

A Tough Business

Despite all the other parallels, general-purpose 3D game engines part company from 3D animation software in one key area: market size. The vendors of 3D animation software had a huge ready-made market awaiting them, with tens of thousands of television, movie, and animation production studios worldwide. In contrast, the market size at this time for 3D game engines can be measured in the low hundreds.

NDL's Austin estimates that there are approximately 250 game developers with the resources to purchase a 3D game engine, about 50 of which already have licensed some type of game or rendering engine. The choices for the remaining 200 are to build their own engine, buy a game-specific engine such as Quake or Unreal, cobble together an engine using component technologies, or buy a general-purpose 3D game engine.

"It's not a big market, and it's a tough business," says Austin. But he adds that he has a significant number of customers who believe they can deliver a better product using NDL's engine and that there are plenty of niches to fill outside the shooter genre.

Peter Laufenberg of Virtually Unlimited says that the key to success within this competitive market is to have a lean operation. "I believe it takes teams of 20 or fewer people who are committed and flexible to be able to take all the turns in the market without choking under heavy fixed costs."

A principal reason for Austin's optimism is the move to recast 2D games as new 3D titles. Two high-profile games are undergoing this treatment using NDL's NetImmerse: *Prince of Persia 3D*, the next version in the popular action/adventure series, and Aeon Entertainment's *Silent Hunter II*, a sequel to the submarine combat-simulation game.

Moreover, Laufenberg sees sub-$500 PCs as a source of good news for general-purpose game engines. The cheap PCs will take games beyond hardcore players, he says, establishing a new market for titles priced at less than $20. This type of game will be developed in six to 12 months for budgets of $300,000 or less. Time and budget pressures will not allow many game developers the luxury of developing engines in house. Instead, they will turn to a general-purpose game engine.

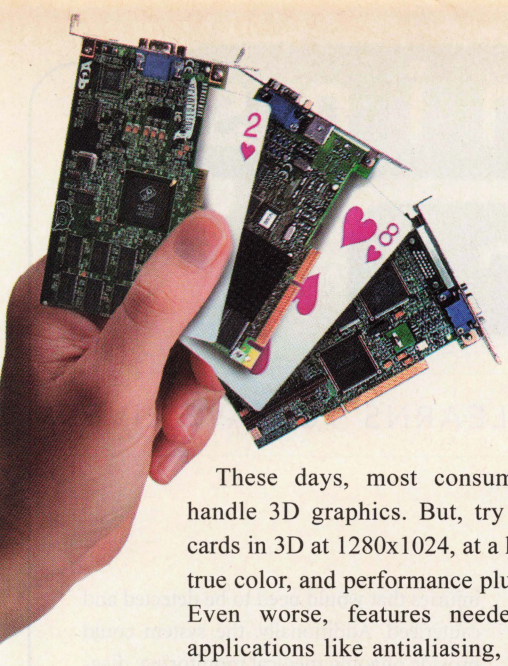
Market Movement

While not overwhelming, considerable evidence suggests that general-purpose 3D game engines are catching on: Major companies—including Digital Domain and SouthPeak Interactive—have licensed NetImmerse over the last year, and 19 titles are in development using the engine. Virtually Unlimited has sold 3DGM licenses for a wide range of projects, including upcoming titles that will be published by GT Interactive, SegaSoft, and Electronic Arts, among others.

The principal threat to this toddling market, according to Austin, is not internally developed engines, game-specific engines, past product failures, or a small market. It's the prospect of Microsoft incorporating technologies into its base platforms that will replicate the core functionality of today's game engines. Another ominous trend is the continuing consolidation of game developers, which could mean fewer potential customers.

As with 3D animation, especially in the early days, vendors might find that the success of their engines is somewhat capricious, hinged to the popularity of specific titles created with the engines. A monstrously successful game title could do for a general-purpose game engine what movies such as *The Terminator, The Abyss,* and *Jurassic Park* did for the 3D animation software used to generate the special effects. Or greater market acceptance could come from game developers realizing, like 3D animation studios before them, that the magic rarely comes from internal programming expertise. "Programmers are important," says Check Six's Joe Enzminger, "but in general, most of the creativity in a game project comes from the design and art side. I have yet to see a good example of 'programmer art.'"

Bob Cramblitt is a freelance writer specializing in computer graphics topics. He can be reached at bobc@cramco.com.



Cards for play.

These days, most consumer-level cards can handle 3D graphics. But, try using one of those cards in 3D at 1280x1024, at a high refresh rate, and true color, and performance plummets dramatically. Even worse, features needed for professional applications like antialiasing, alpha blending, and stencil planes may not even be supported. And, while most of these cards claim OpenGL readiness, they haven't been tested with key applications. If you're a professional using 3D CAD or animation applications, you need a card that means business.

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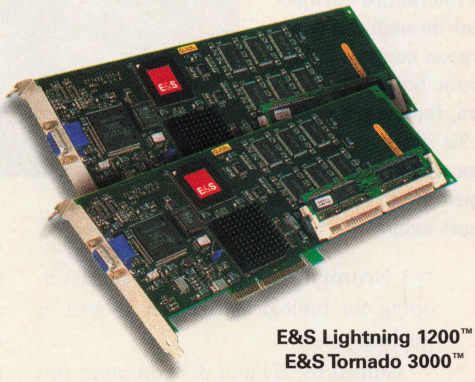

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# of spaceships and surgery

AN IMAGE-GUIDED SENSOR FROM NASA LEARNS TO SAVE LIVES

BY DIANA PHILLIPS MAHONEY

It takes years of medical training and practical experience for physicians to hone certain diagnostic and treatment skills. It takes minutes for an image-guided robotic technology being developed by NASA to do the same thing. Called the Smart Probe, the device is a real-time, computer-based diagnostic and surgical tool that researchers in the space agency's NeuroEngineering Group are developing for biological research as well as medical care.

A graphical interface serves as a window into the interactive environment through which a surgeon controls the robotic Smart Probe. Here, the surgeon relies on 3D ultrasound data to position the sensor-tipped probe to "see" a breast lump.

Guided by 2D and 3D computer images in a virtual environment, the probe employs a tiny, needle-like sensing mechanism in conjunction with hybrid fuzzy-logic neural-network software that uses feature-extraction and pattern-recognition techniques to identify, characterize, and analyze the properties of tissues under investigation.

The list of potential medical and research applications of this technology is endless. NASA's ultimate objective is to utilize various implementations of the Smart Probe on space missions. Toward this end, the researchers are pursuing applications ranging from geological exploration to remote medical care to biotechnology. For geological investigation, for example, "we're 'training' the probe on geological specimens on Earth. Then, we'll use it to study specimens from remote planets-to learn what's there and compare it to what's on Earth," says Dr. Robert Mah, principal investigator on the project. The goal is to be able to conduct autonomous explorations in which the system would alert the operator only when it finds regions of interest.

On the medical side, the researchers are developing a minimally invasive tool to aid in handling medical emergencies on long-range space missions. For example, doctors on board the spacecraft could operate the probe to diagnose and treat certain life-threatening medical conditions of the astronauts—such as internal bleeding due to injuries that would need to be detected and cauterized. Additionally, the system could provide ongoing medical monitoring, diagnosis, and treatment to astronauts.

The Smart Probe is also expected to facilitate "humane" animal studies that will help scientists understand how humans could survive on the yet-to-be built space station. "NASA hopes to be able to do real-time biopsies to determine how animals are affected by zero gravity or artificial gravity," says Mah, "rather than sacrificing the animal and freezing the tissue for study back on Earth." The tool can also be used to monitor changes periodically over prolonged exposure to the space environment.

Down-to-Earth Applications

While the researchers pursue these long-term goals for the Smart Probe, they are also setting their sites on non-space-related applications that are closer to fruition. Specifically, they are developing minimally invasive tools for neurosurgery and breast-cancer diagnosis.

In the neurosurgical system, surgeons, guided by magnetic resonance images (MRI) of the patient's brain on the computer screen, insert the robotic probe into the brain. The sensing mechanism measures the tissue it encounters, and the hybrid neural-net software "learns" the brain's characteristics and represents the information visually on the screen.

"Everything is graphical," says Mah. "There are radio rays emanating from the tip of the probe, and the length of the rays are proportional to the stiffness of the tissue that's being sensed. On the display, there are color bars that vary depending on what tissue is being interpreted by the

sensors." The objective of the visual display, he says, "is to take numbers [measurements representing tissue characteristics and orientation, and the system's degree of confidence in its determinations] away from the surgeon." Additionally, a 3D model of the skull provides surgeons with orientation cues.

This interactive visualization scenario is achieved through a virtual environment built with WorldToolKit software from EAI/Sense8 (Ames, IA).

The researchers are also planning to incorporate a force-feedback component for surgeons to use as an interactive interface for exploring the tissue at the tip of the probe. They are experimenting with various types of sensory feedback, such as the pressure of force applied to the tissue and the partial pressure of oxygen or electrical fields.

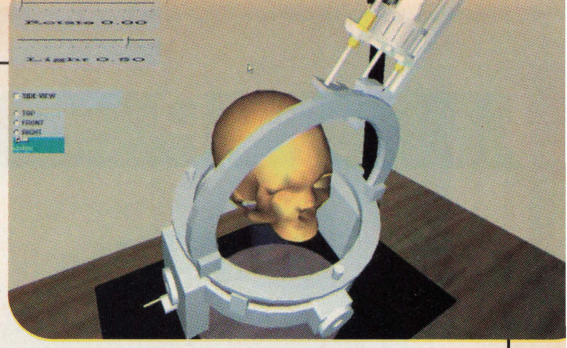
Once fully developed, neurosurgeons will be able to use the robotic imaging system to obtain real-time biopsy results or to obtain tumor samples for more extensive biopsy analysis. Currently, surgeons obtain tumor samples by inserting a biopsy probe through an opening in the skull, guided only by a 2D MRI image. The surgeon has no real-time feedback about the structures being encountered along the way. "As it enters the brain, there may be injury to brain tissue. If an artery is damaged as the doctor inserts the probe, the patient could have a stroke," says Mah. In contrast, the software-driven robotic device controls the speed and maximum pressure of the probe as it's being inserted. If it encounters an artery, it will stop before it penetrates.

The neurosurgery system is not yet ready for its clinical debut. The biggest obstacle it has yet to overcome is its reliance on static MRI imagery. "Those scans are taken before the operation, so they don't account for errors introduced during surgery," says Mah. "The brain is very soft, so [the structures] shift. If the tumor is pretty deep, as you push the probe in, the brain gets compressed and the target moves, increasing the possibility of damage." Ideally, the system would utilize real-time insertion of new MRI data. Unfortunately, the imaging technology hasn't yet progressed far enough to accommodate such a scenario. For instance, metallic surgical devices interfere with the magnetic mechanism of traditional MRI systems, making them ineffective in an operating room. Only a few MRI systems in the world have been adapted for use in operating rooms.

Diagnosing Breast Cancer

Mah is able to use real-time images in the breast-cancer diagnostic system, because this application uses ultrasound data collected via a portable transducer. The transducer is attached to a mechanical arm that communicates the sensor's orientation to the computer. Mah is working with Sense8 to create a virtual environment incorporating the live scans.

As in the neurosurgery application, the ultrasound imaging data in the breast cancer application serves as a visual guide for the Smart Probe, which is programmed to "see" a lump and determine by its features if it is cancerous. Additionally, scientists may be able to teach the device to predict how the disease may progress. According to Dr. Stefanie Jeffrey of Stanford University School of Medicine who is working with Mah to develop the device, "We hope to use it not only to detect cancer, but to understand the nature of an individual cancer. This information may help us determine the distinctive features of malignancy and how the disease may progress." Ultimately, she says, more knowledge about the cancer can lead to improvements in individualized treatment.

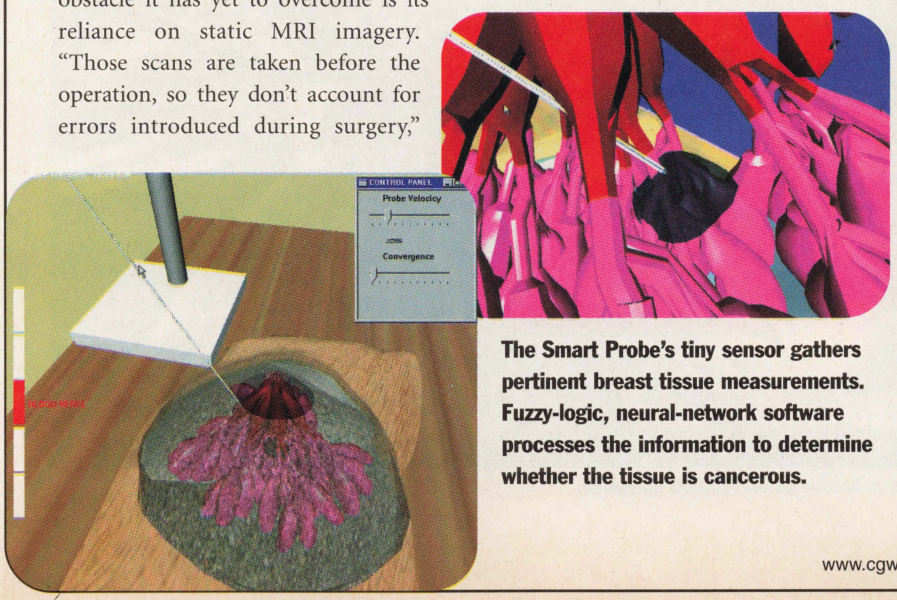


A 3D model of a patient's skull provides surgeons with location and orientation cues for directing the robotic Smart Probe in neurosurgery applications.

Before either the neurosurgery or breast cancer tools can be commercialized, the researchers have to collect enough clinical data to establish a satisfactory degree of confidence in the measurements and interpretations. "To get anything through the FDA, you need to have a lot of data," says Mah. The researchers are also working to improve the technology by miniaturizing the sensor's tip and enhancing its sensing mechanisms. Mah is confident the technology is the precursor to the next generation of surgical tools. "In the future, surgeons are going to be measuring everything with mini sensors to get tissue 'fingerprints,'" he says.

Although the medical focus of Mah's development efforts has been in neurosurgery and breast cancer, the technology is application-independent, and thus could be used in tools for diagnosing and treating cancers found in other parts of the body.

And the graphical environment will provide a key to the technology's ultimate acceptance and application. "Instead of looking at numbers to tell you if something is cancer, or what grade of cancer it is, we have a high-dimensional space that shows the results visually," says Mah. "As the probe enters the body, you're looking at the graphics as if you're at the tip of the probe. You can see muscle as you approach and enter it. As you begin to go through cancer, you can see that. It's a much more intuitive approach than trying to interpret numbers on a page."



The Smart Probe's tiny sensor gathers pertinent breast tissue measurements. Fuzzy-logic, neural-network software processes the information to determine whether the tissue is cancerous.

Diana Phillips Mahoney is chief technology of Computer Graphics World.

"Corbis Tree." Built in B splines with Real 3D (no polygons).

Digital Fine Art

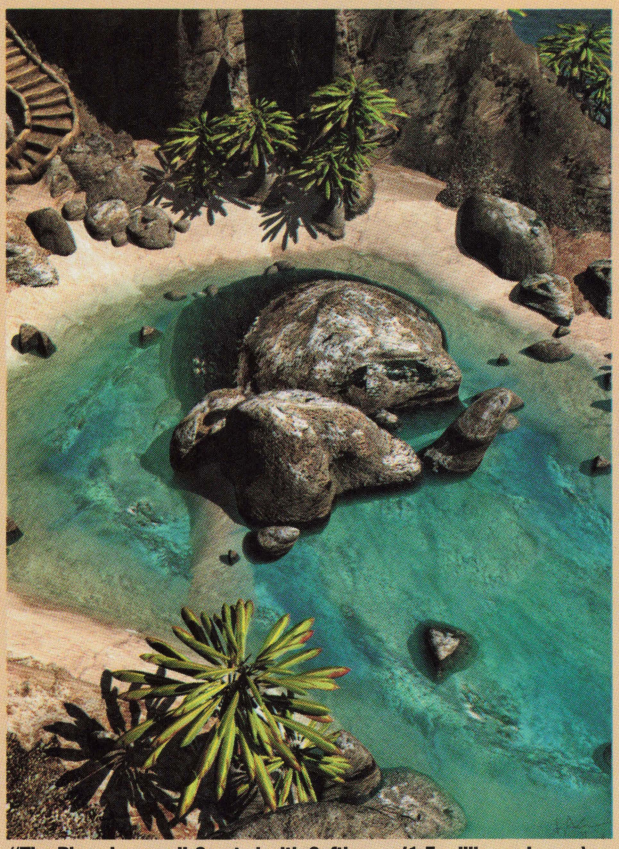
Los Angeles artist Jeremy Engleman likes to push the computer graphics medium to get at what is painterly about it, "but this does not mean I am trying to make CG look like a painting through the use of push-button art filters. Rather, I am trying to identify what can be painterly and beautiful about computer graphics' own nature." The result is work that more closely resembles fine art produced by oils on canvas than images created with software on a computer. "CG is such a chameleon; it can look like so many things—a photograph, a cel shade, or a painting. So I am trying to push CG in its own terms, in ways unique to CG itself," he says.

While some of Engleman's work involves thousands of polygons (*The Bather*, for instance, comprises approximately 25,000 of them), the artist strives for a certain economy in his art by using minimal geometry. "I typically restrict my image output size and color range. I love pixels, and I like to be able to see and manipulate each one. However, if my resolution is too large, I loose individual pixels."

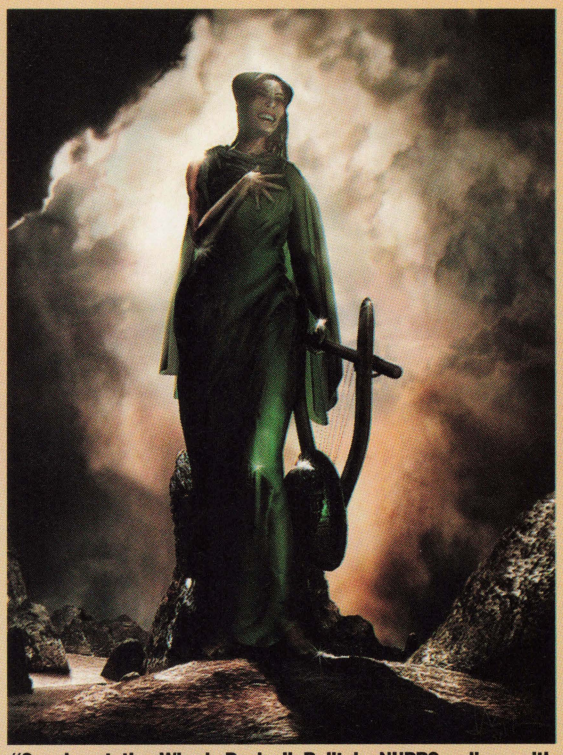
To create his work, Engleman uses a variety of programs, depending on the task at hand. Most frequently he uses Softimage (Montreal), Lightwave (NewTek; San Antonio, TX), and 3D Studio Max (Kinetix; San Francisco), though he notes he is not an advocate of any particular package. "I may work on a model in all three packages, depending on what I need to do with it, then render in any one of those. This also helps keep my work platform-independent. Each package often has a particular discernable 'look', and I would like the image to be about itself, not the software," he says.

Additional images by Engleman can be found on the *Computer Graphics World* Web site (www.cgw.com). For more information about the artist and his work, visit www.art.net/~jeremy. —*Karen Moltenbrey*

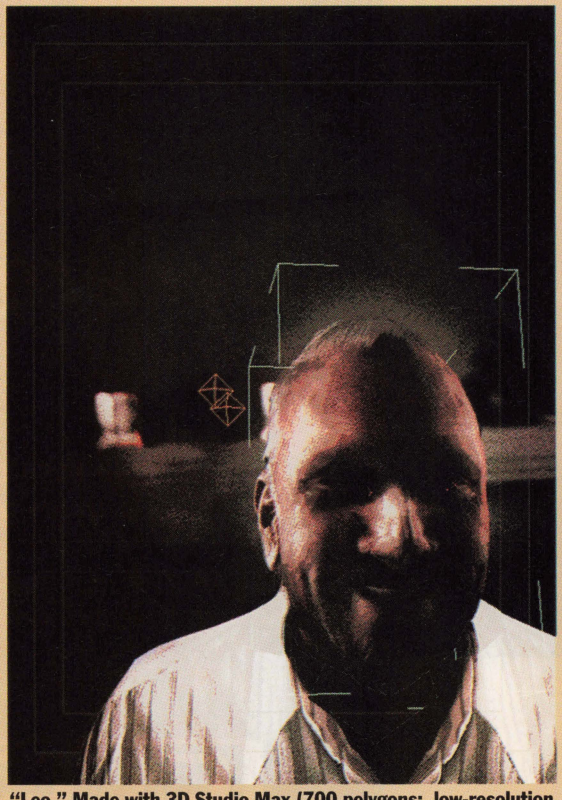
"Still Life with Spider Plant." Built with NURBS splines in Softimage 3D (30,000 polygons).



"The Riven Lagoon." Created with Softimage (1.5 million polygons).



"Sappho at the Whark Rocks." Built in NURBS splines with Softimage 3D (300,000 polygons).



"Leo." Made with 3D Studio Max (700 polygons; low-resolution textures).

"The Bather." Hand-modeled with Lightwave 3D (25,000 polygons; virtually no textures).

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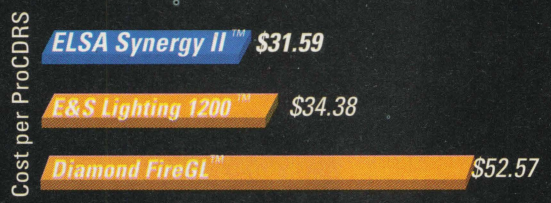

❖ The test results were completed on a 500 MHz Pentium III system running Windows NT 4.0 at 1280 x 1024 in true color.

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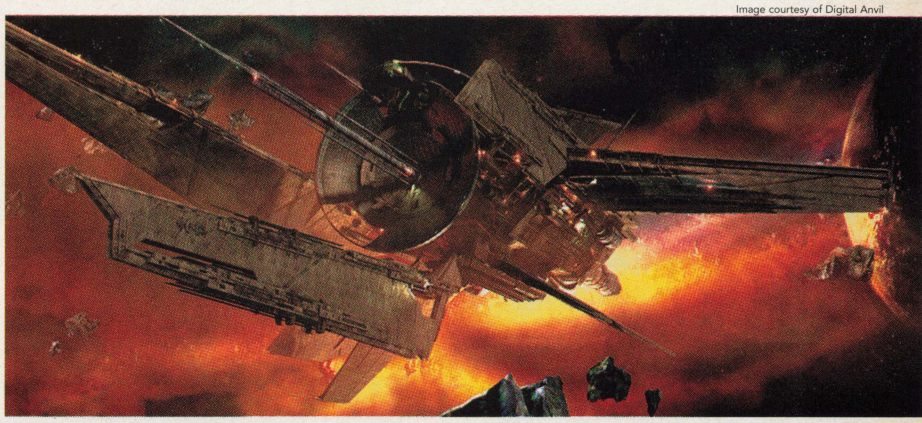
FILM

FLYING HIGH

PC game creator takes his space battles to the big screen

BY KAREN MOLTENBREY

Image courtesy of Digital Anvil



To create realistic space environments for *Wing Commander*, Digital Anvil artists used colors and textures from photographs taken by the Hubble Space Telescope.

About a decade ago, when most people his age were obtaining a college education, an ambitious Chris Roberts was teaching the gaming community a lesson or two when he created *Wing Commander*, a PC game with such stunning high-quality 3D special effects for its time that it seemed more like an interactive movie than a computer game. Since then, Roberts has continued to break new ground: *Wing Commander II* was the first computer game to use Kinetix (San Francisco) 3D Studio software, *Wing Commander III* was the first game to use an interactive movie and marked the first extensive use of full-motion video, and *Wing Commander IV* was the first game to use 35mm film for its narrative. Now, Roberts has hit another milestone: He is the first person to bring a PC game to the big screen as a full-length feature film.

The *Wing Commander* movie, created and directed by Roberts, is based on the characters and themes from the top-selling games of the same name. The $27 million film, set in the year 2564, documents the exploits of a young pilot (played by Freddie Prinze Jr.) fresh from the Academy who joins the Confederate forces to quash an alien attack from the invading Kilrathians, a cat-like species who have captured a computer navigation device that will enable them to attack and destroy Earth. But the sci-fi flick is infused with many 1940s military references and style, making it, according to Roberts, "a hard-core war movie set in space in the distant future."

Although *Wing Commander* represents Roberts' film directing debut, the role is not entirely new to him. He has directed actors—for instance, Mark Hamill and Malcolm McDowell—in extensive live scenes during production of the third and fourth game series. "The *Wing Commander* games were so successful because they became increasingly cinematic—we shot on film and had motion-picture production values. Each time it was like making a film, so going to the big screen felt like the next logical step," Roberts says.

While the film retains *Wing Commander*'s origins, Roberts walked a fine line, being careful not to ignore the games' loyal following, but taking advantage of today's technology and the chance to attract a whole new audience. "The film delivers all the action and visual impact that *Wing Commander* fans expect. Yet we insisted that it also have mass appeal. We worked with a brand-new story line, so moviegoers don't have to be familiar with the game to understand or enjoy the film," he says.

Breaking with Tradition

The drama, distributed by Twentieth Century Fox, was created untraditionally by Hollywood standards. For the live action, production designer Peter Lamont, who recently received an Academy Award for his work on *Titanic*, created a retro-futuristic world by transforming two sound stages in Luxembourg, Belgium, into the flight deck, bridge, and corridors of the Confederate carrier *Tiger Claw*, as well as the bridge of the merchant vessel *Diligent* and the bridge and corridors of the Kilrathi ship. The footage was then integrated with about 300 effects—all digital—most of which were created by Roberts' entertainment company, Austin-based Digital Anvil. Roberts formed the company more than a year ago when he left Origin Systems (a subsidiary of Electronic

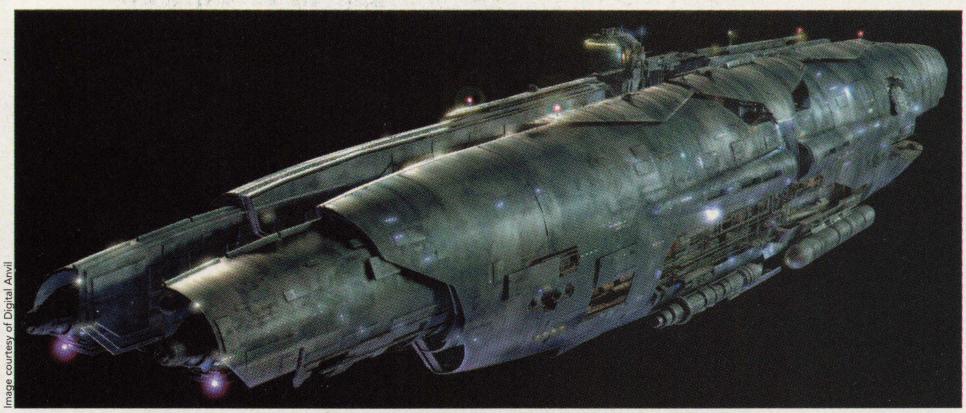


Image courtesy of Digital Anvil

The artists designed digital spaceships that looked war-torn and battle-scarred, adding to that look as the film, and the battles, progressed.

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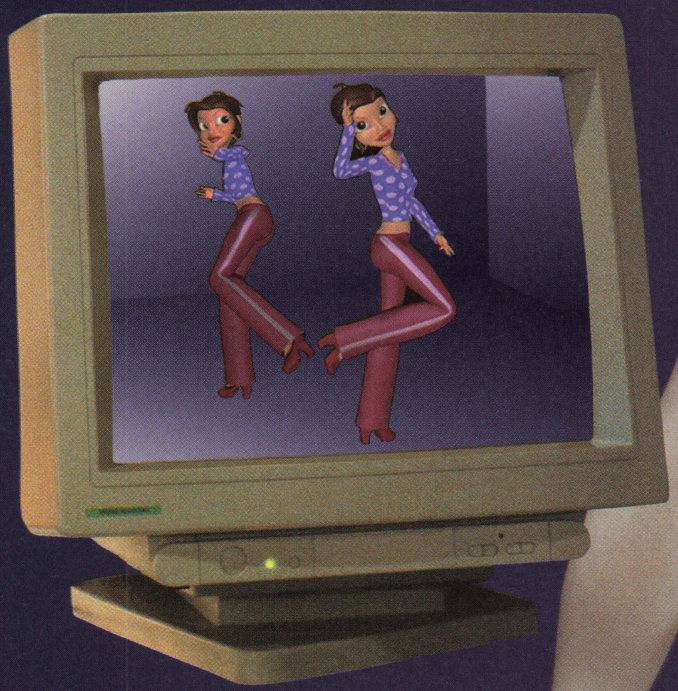

*Modern Cartoons' **Cyber Lucy**, the hottest animated game show host in Television, moves as naturally as her human counterpart thanks to **MotionStar**.*

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Cyber Lucy courtesy of Wheel of Fortune 2000 [or Game Show Network]

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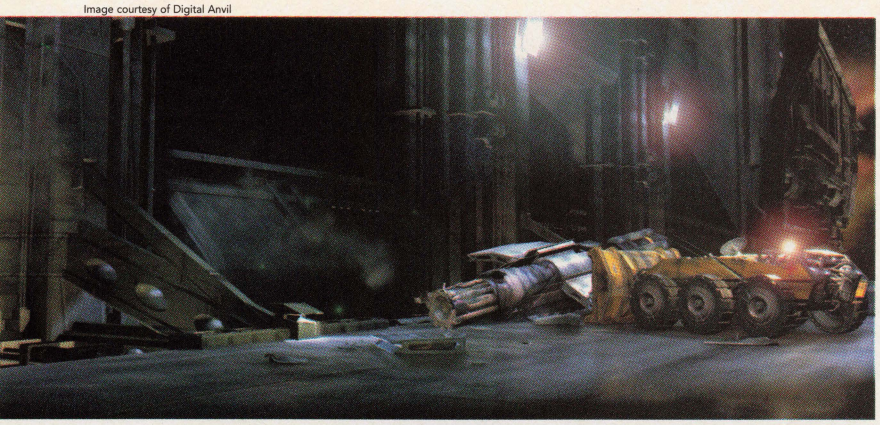

Because Digital Anvil had a small animation staff, many artists had to assume various roles, going from modeling the spaceships to completing the effects for shots such as this.

Arts, which released the *Wing Commander* games), after securing film rights to the series.

The animators at upstart Digital Anvil hit the road running, completing all but 20 of the film's effects, while also creating content for four new computer games, scheduled for staggered releases throughout the next 12 months. "The biggest challenge was putting together a digital-content team of 20 people—most of whom never worked together before—outfitting them with new software in a new facility, then trying to produce about 300 digital effects for a feature film," says Chris Olivia, Digital Anvil's visual-effects director, who served as sequence supervisor for the movie. Complicating the situation were the diverse backgrounds of the animation team—some came from gaming, while others grew their roots in the commercial effects field—who helped fulfill Digital Anvil's focus of an all-around digital-effects house. "We borrowed from both sides. We took the organizational production from the film side, and let people wear many different hats—modeler, texturer, animator—from the game side," he adds.

To help the company maximize its resources, it used off-the-shelf products to produce the film's effects. For almost all the CG work, the animators used Alias|Wavefront's (Toronto) Maya, running on SGI (Mountain View, CA) Octanes, for building, texturing, and animating. For the rendering, the group used Maya running on a distributed system comprising 30 NT-based Boxx Technologies' (Austin) RenderBOXXs and SGI Octanes, Origin 200s, and O2s. For compositing, the animators chose Maya Composer and Nothing Real's (Los Angeles) Shake.

"We didn't use a digitizer or anything like that. We built everything directly in Maya from drawings provided by the artists," says Olivia. He adds that the only physical models used for the film were those provided by the art department as a guideline for the animators. The decision to avoid practical models was driven by time and money, but mostly because "we also knew we *could* do it digitally; we have a lot more experience in that arena."

According to Olivia, almost all the digital effects performed by Digital Anvil were 100% 3D, with no live action. Although *Star Trek: Insurrection* beat *Wing Commander* to the screen with an all-CG star fleet and fully digital space sequences, Olivia believes the level of detail in the ships and the realism of *Wing Commander* is superior. "The film contains a full atmospheric, colorful look at space, instead of the blackness and void commonly depicted. So you have a lot of things like pulsars, nebula, and quasars that occupy these 3D environments," he says.

In fact, while Roberts notes that the CG work on the movie was fun, it was not exactly like creating a game, in that the resolution is much higher and the amount of detail is far greater in film, requiring more attention. Adds Olivia: "You just can't hand the images over to be digitized. You have to be aware of how everything will look when it is magnified about eight times."

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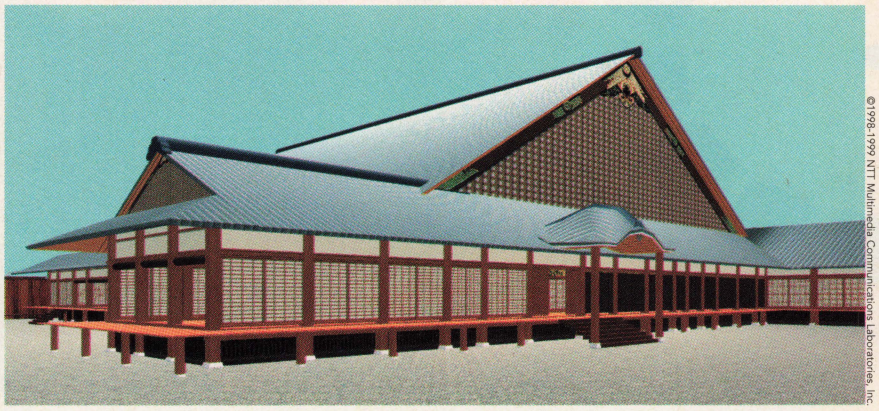
VIRTUAL REALITY

RELIVING THE PAST

NTT's InterSpace VR technology transports viewers back in time to the streets of historic Edo

BY KAREN MOLTENBREY



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Using its InterSpace technology, the NTT Multimedia Communications Laboratories (MCL) group developed an interactive VR experience for museum-goers, where users can explore a virtual re-creation of the city of Edo.

The Japanese city of Edo, which is now present-day Tokyo, is long gone, destroyed by fires and earthquakes more than a century ago. However, visitors at the National Gallery of Art's recent Edo exhibit in Washington, DC, had the unique opportunity to not only view art and artifacts recovered from this 250-year period of artistic proliferation, but to put those works of art into their original context. Using one of six computer kiosks adjacent to the exhibit, museum-goers were transported back in time with a virtual-reality program that enabled them to visit Edo Castle (the ruling shogun's residence and audience hall), as well as the city's theater district, its "pleasure quarter," and a shopping district.

"The exhibit was comprehensive, containing many works that had never been seen outside of Japan—and some that are rarely exhibited even within Japan," says Rob Rothfarb, virtual-worlds creative director for Nippon Telegraph and Telephone Corp.'s (NTT) Multimedia Communications Laboratories (MCL; Mill Valley, CA), creators of the virtual Edo. "The gallery wanted a supplemental experience to help put those items into architectural and cultural context. They wanted to give people a sense of what it was like to walk around the streets and famous sites of Edo."

The VR program, called *Exploring Edo*, was developed with NTT's InterSpace technology, a multiuser virtual-reality platform that incorporates 3D environments, streaming audio and video, and high-resolution digital photos. "We re-created four areas of the city so people could take a tour, see some highlights, and familiarize themselves with the city's splendid architecture, since all, or most, of it was lost within a 20-year period in the late 19th century. We also incorporated digital objects from the exhibit and placed them into context, showing their location and how people would have used them," Rothfarb says. For example, in the Yoshiwara, or pleasure quarter, you can see a video clip of a shamisen (a three-stringed lute) that would have been played by courtesans, and in Edo Castle, you can view a model of the shogun's samurai sword.

To create those scenarios, however, required extensive research. "We collaborated with an expert in Edo history, Dr. Bruce Coats of Scripps College in Claremont, California, along with historians and curators from the National Gallery of Art, to conceptualize the virtual worlds so we would know exactly what we were trying to build in 3D," Rothfarb says.

Rothfarb and 3D designer/virtual-world developer Bill Niemeyer performed all the modeling and texturing for the project using Kinetix's (San Francisco) 3D Studio Max and Adobe Systems' (San Jose, CA) Photoshop, respectively, running on various Windows platforms, including NT.

"We created a lot of the textures from scratch, while others we took from frame grabs and scans. For instance, there are about 100 painted panels featured inside the castle environment that are exact images of the kano-style panels that were actually inside Edo Castle," Rothfarb explains. "The panels were destroyed long ago, but what survived were scrolls of actual sketches the artists made more than 150 years ago." The group scanned transparencies of those images and then placed the 3D replicas within the castle, using historical references to ensure that their locations

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To create the richly textured interiors of Edo Castle, the artists used a combination of hand-tooling, frame grabs, and scans.

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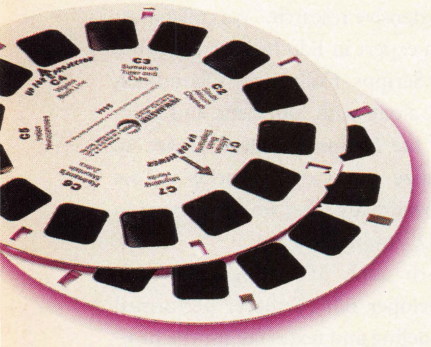

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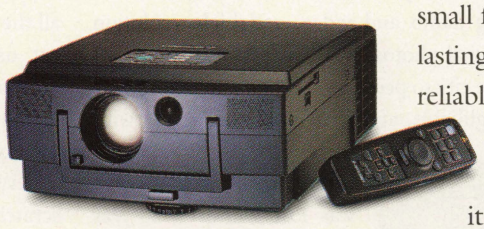

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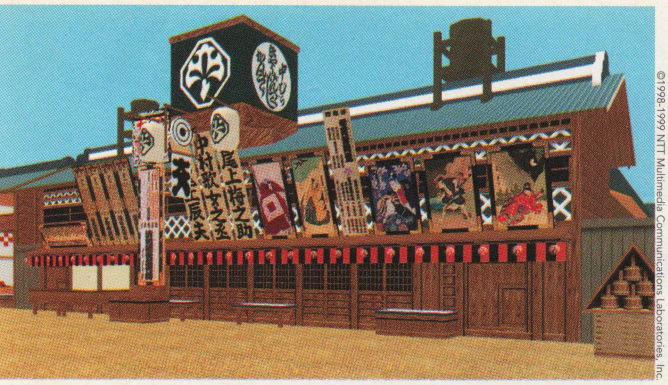
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To help provide a real-time experience, the animators divided the VR program into four environments, such as this theater, in which the user can maneuver.

were accurate. In other instances, when scanned textures were unavailable, the group created a palette that was representative of the period, and colored the 3D objects manually.

Once the models and textures were completed, the group imported them directly into NTT's InterSpace program, which contained a script developed by Yoichi Kato, director of NTT MCL, that defines how viewers would move through the virtual model, as well as the lighting and interactivity. Rendering was performed in real time using InterSpace.

The group also incorporated approximately 40 hot spots into the VR program, which, when selected, would engage a prerendered sequence or a video-clip pop-up garnered from period dramas, films, and educational documentaries, or created from the Edo art work. For instance, when a fan icon is selected in the theater district (Saruwaka-machi) environment, a pop-up displays a clip from a Kabuki play or puppet theater performance, while a hot spot in the shopping district (Nihonbashi) environment displays a video showing how the various goods—wood crafts, sweets, and lacquerware—were produced.

Environmental Issues

Although this seems like a lot of imagery for a single VR segment, the program was divided into four environments. When the user chooses one from the main menu, it is loaded for viewing. The largest, most elaborate environment is Edo Castle, which contains about 6250 polygons. In order to run the program efficiently, Rothfarb and his colleagues optimized the geometry "so any polygon that you could not see [from your viewpoint in an environment] is deleted," he notes. "It was just like creating a very large virtual set."

Because the developers were able to choose the kiosk platform, they could ensure that the rendering quality and frame rate were suitable for the museum exhibition. For the kiosks, they chose Pentium IIs with 3D graphics accelerator cards powered by the nVidia (Santa Clara, CA) RIVA TNT chipset. However, the group also had to consider the broader picture, since the program was also being distributed to museum visitors as well as classrooms throughout the US on CD-ROM and via the Internet. Although the Internet version lacked many hot-spot features due to copyright issues, it did provide the added feature of allowing multiple users to explore the historic city together using avatars.

"We had to choose a minimum target [platform] for home and classroom users, which forced us to think about available texture memory and processing power on a typical multimedia PC. So we optimized the program for a Pentium running Windows 95 or 98 with a 3D accelerator containing 4MB of video RAM. We used the same 3D model for kiosks, with their accelerated hardware, as well as for the CD-ROM and Internet versions," explains Rothfarb. "The trick was optimizing the geometry from the beginning to make sure we had the fewest number of polygons possible. Although there are some tools available for reducing geometric complexity, we relied on optimizing the models by hand since we could make the best decisions about which polygons were unnecessary." However, the resolution of the texture maps for the CD-ROM and Internet versions was reduced to half that of the kiosk version, which was achieved using Photoshop and Equilibrium's (Sausalito, CA) De-Babelizer.

In all, it took the NTT team almost five months to complete the project. While the modeling, texturing, and programming proved challenging, one of the most difficult and time-consuming aspects was the extensive research to make the presentation as historically accurate as possible—after all, the project was presented in conjunction with the museum exhibit. "We set our 3D modeling systems to use the exact building scales and measurements that carpenters and craftsmen used historically in Japan—and it wasn't feet or inches!" says Rothfarb. "To ensure that the models were made to scale and textured accurately, we used drawings, prints, and other art and architectural references we had access to."

Key Tool **InterSpace**; NTT Multimedia Communications Laboratories; www.nttinteractive.com **infoNOW 100**

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The artists also produced this Internet version of the VR program, called *Virtual Edo*. A group of high school students in Maryland used the program to take a virtual field trip to Edo as part of an NTT-sponsored distance-learning event.

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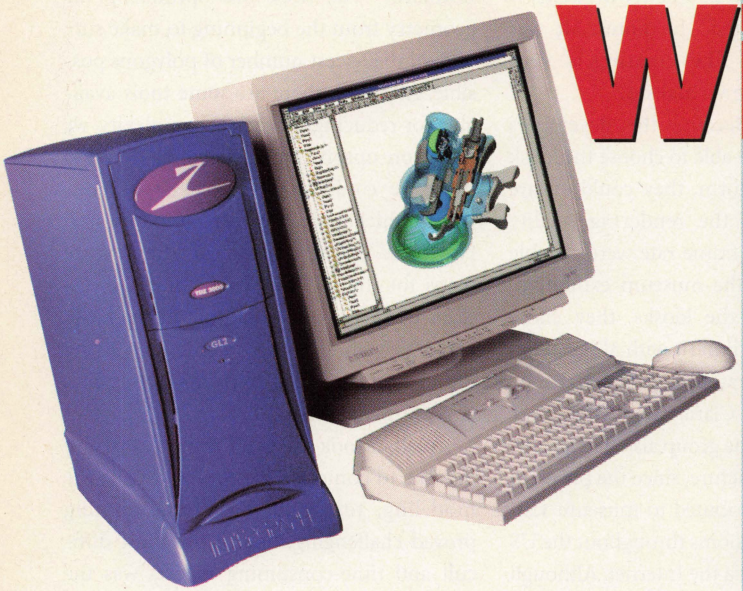

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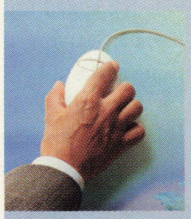

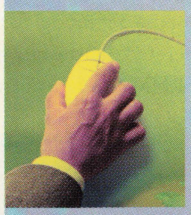

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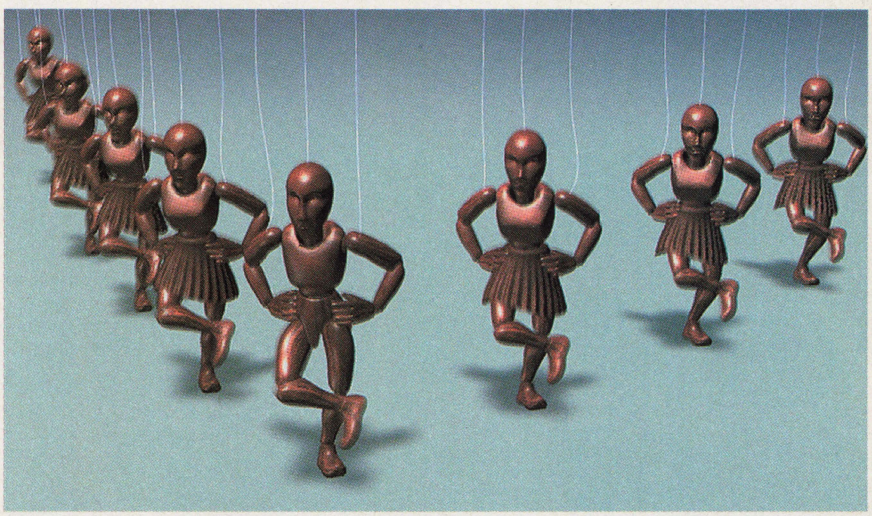
KEEPING IN STEP

Marionettes dance to a new tune—3D animation

BY KAREN MOLTENBREY



Using 3D animation and the company's proprietary Jitter program, artists at Toybox were able to realistically animate a line of Celtic-dancing marionettes—and retain an old-fashioned look.

There were no strings attached to the marionette puppets dancing to Irish music in a recent commercial for Robaxacet pain-relief medication. By using 3D animation, Toybox, the visual-effects division of Toronto-based media services provider Command Post, was able to retain the traditional look of the marionettes while providing them with some fast-stepping dance moves.

The 30-second spot, airing in Canada, uses the original concept of two marionette puppets from previous Robaxacet spots as the basis for an animated dance troupe whose moves mirror those of popular Celtic dancers. In the past, Robaxacet has used the puppets in a series of commercials, first featuring actual marionettes, then using traditional stop-motion techniques (moving the action frame by frame). In fact, for one of the stop-motion spots, an actual puppet was also used. "We sold them on the idea of converting the [puppets] into 3D animation for a Riverdance-like performance, which enabled us to perform more movement," says Derek Grime, Toybox animation director.

According to Grime, using 3D animation techniques enabled the group to feature a line of 30 puppets dancing in unison to Celtic-inspired music. "If we would have used stop motion, we would have had to animate all 30 dancers by hand or animate one of them and clone it, which would have looked unnatural [in the segment]," he says. "By converting them to 3D, we could put as many dancers as we wanted on the screen at one time."

To retain the character of the original puppets, Grime, along with animators Raymond Gieringer and Mark Stepanek, used the 2-foot-high, wood-carved marionettes from the earlier commercials as references for their 3D models. The group built and textured the models using Alias|Wavefront's (Toronto) Maya running on a combination of SGI (Mountain View, CA) O2 and Onyx workstations.

"The client was concerned about changing to a new medium; they didn't want to lose the character of the actual puppets, since they are well known," Grime says. "They didn't want anyone to know [the puppets] were on the computer because the whole basis for using the marionettes was to project their old-world feel. They certainly didn't want them to look high-tech."

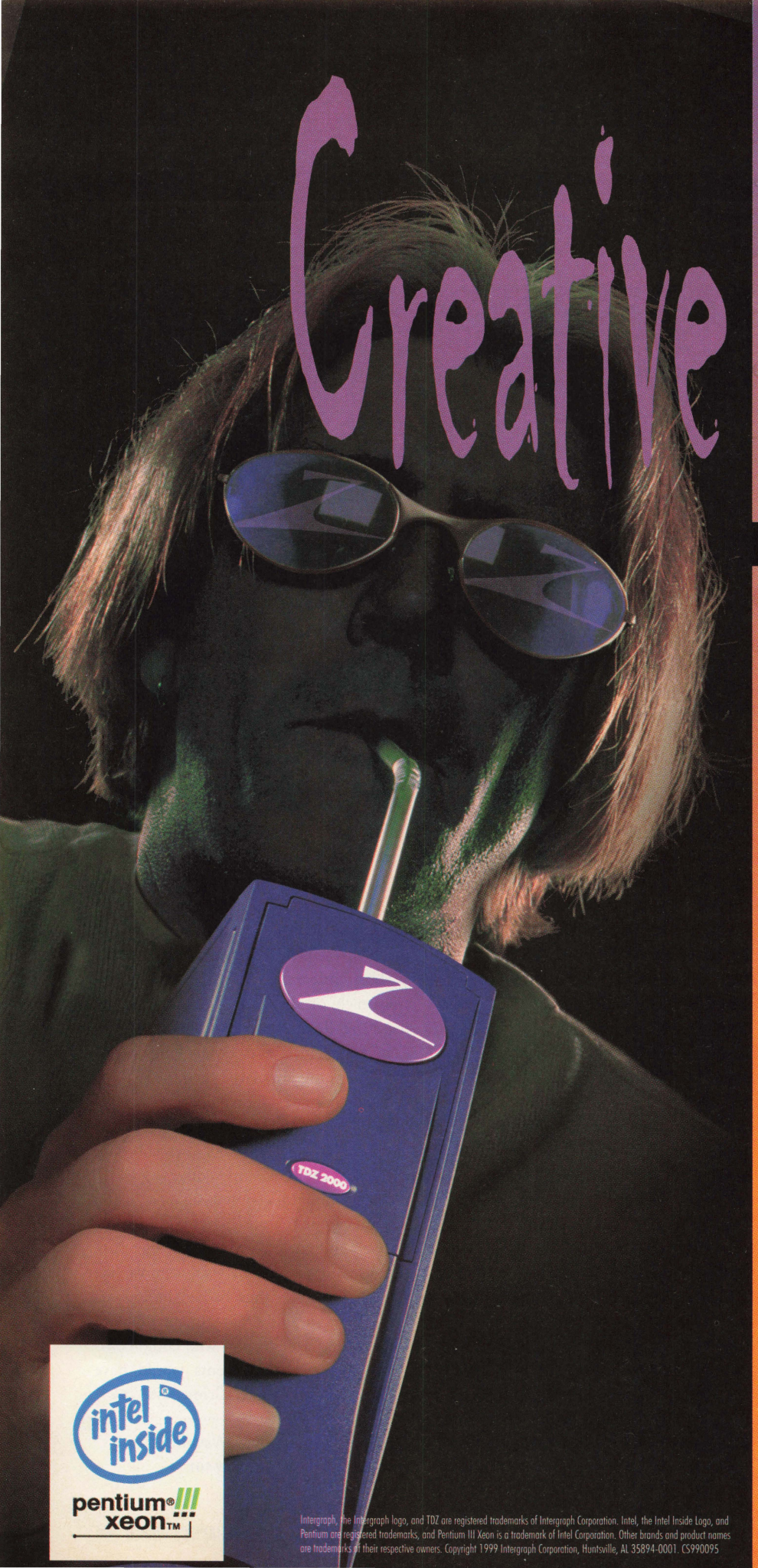
To accurately mimic the dance steps, artists from Toybox and Red Rover (Toronto), a 2D animation house, studied reference footage of Celtic dancing, which entails fast, repetitive steps. To replicate this action, the Red Rover team used traditional 2D character animation to create an animated dance cycle, which was viewed by the client early in the process. Once approved, the animators at Toybox scanned the traditional animation into the SGI workstation and loaded the cycle as an image plane in Maya. The 3D animators then used the background cycle as a guide to drive the motion of the 3D character.

"The animators at Red Rover already created a good looping dance step for us, so we used that as our base instead of starting over from scratch," explains Grime.

Once the movement was completed in 3D, Grime's group repeated the moves in the animation cycles of the 29 other puppets. To make the sequence appear more realistic, Toybox wrote a piece of software that controls each of the dancer's limbs, placing them slightly out of step from one another. "The lead dancer was driving the others. Our Jitter program placed them out of step just enough so they didn't look cloned," says Grime. "Without this software, we would have had to tweak all the limbs, which would have taken about five times longer to do."

The animators opted against using motion capture because it would have produced a stilted look. "The characters are supposed to be marionettes that move like Celtic dancers, so they had to be loosed-limbed but perform a regimented dance step. To find a performer who could combine those two movements would have been almost impossible," Grime says.

Key Tool **Maya**; Alias|Wavefront; www.aw.sgi.com infoNOW 101



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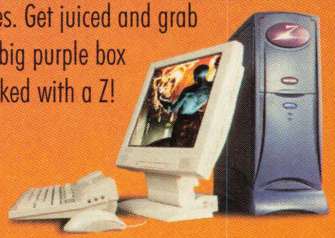

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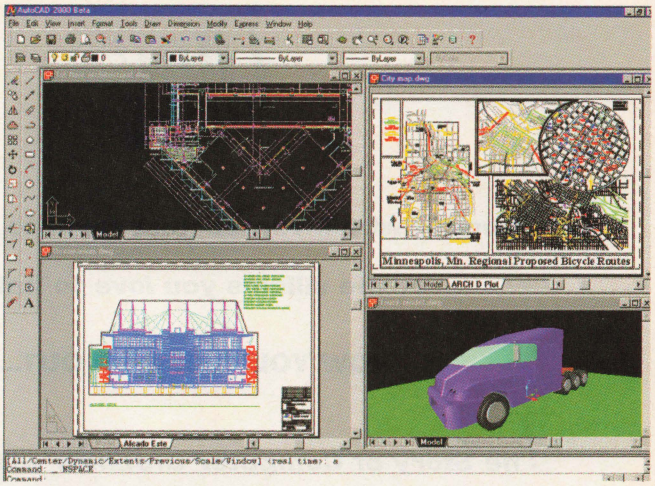
AutoCAD 2000

Autodesk responds to user requests

BY DAVID COHN

AutoCAD 2000, the successor to Autodesk's AutoCAD Release 14, contains 400 improvements that fall into five main areas: heads-up design environment, improved access and usability, expanded reach, streamlined output, and greater customization and extensibility.



With AutoCAD 2000's Multiple Design Environment, users can open, edit, and design within multiple drawings in a single session. Each drawing can have multiple paper space layouts, which can include non-rectangular viewports.

Heads-Up Design

Users' number one wish-list request has finally been fulfilled: AutoCAD can open multiple drawings. But rather than stop there, Autodesk made its Multiple Design Environment (MDE) truly elegant. You can open multiple drawings, drag and drop objects between them, and even paint properties such as color, layer, and line type from one drawing to another. And, while working in a drawing, you can edit blocks and external references within it, then save your changes back to the reference drawing or block definition.

AutoCAD's real-time pan and zoom features are now more intuitive when used with an IntelliMouse-compatible pointing device. You can work in either shaded or wireframe 3D views and perform real-time rotation and zooming of those views.

Access and Usability

In previous versions of AutoCAD, when you right-clicked the mouse, the software reacted as if you had pressed Enter. Because AutoCAD by default repeats the previous command when you press Enter, you would therefore be activating a command whenever you right-clicked. In AutoCAD 2000, this Windows-interface feature is leveraged to its full potential. Right-click on anything—drawing objects, the command line, a menu, or a toolbar—and AutoCAD displays a shortcut menu providing access to properties and commands.

A new Layer Properties Manager dialog box provides more intuitive control over layers, which can now have up to 255-character layer names, including spaces and both upper- and lowercase characters.

Expanded Reach, Streamlined Output

AutoCAD's Internet Utilities have been thoroughly integrated with the program. For example, when you open, insert, or save a drawing, you can do so across the Web as easily as on your local machine.

In previous versions of AutoCAD, Autodesk incorporated the notions of model space and paper space. Model space is a one-to-one mapping of units in a world Cartesian coordinate system in which the 2D or 3D model resides, and paper space is a one-to-one mapping of units to the size of the piece of paper on which the drawing will be plotted. Users were limited to only one paper space, so if you wanted to plot different versions of the same model you would have to turn layers on and off in paper space in order to plot the various versions.

In AutoCAD 2000, Autodesk has replaced paper space with a new Layouts feature that lets you compose on a virtual sheet of paper. Think of it as a WYSIWYG plot preview. You can create multiple layouts, which appear at the bottom of the drawing window as individual tabs.

Plotting and layouts are likely the most powerful and the most confounding enhancements. In fact, long-time users may have to learn how to plot all over again, which Autodesk has anticipated with the inclusion of a new plotting guide.

Customization and Extensibility

This final area of improvement opens AutoCAD's open architecture even further, with the incorporation of an integrated Visual LISP Development Environment.

With all the changes, there are bound to be problems. Autodesk has tried to anticipate these by including a Migration Assistance package that lets users batch-convert older drawings into the new format, analyze existing AutoLISP programs, and adapt pre-existing custom menus and toolbars.

After extensive beta testing, AutoCAD 2000 is reported to be incredibly stable and in most respects faster than Release 14. By basing its enhancements on the needs and desires of its users, Autodesk has delivered a winner.

David Cohn is a consultant and technical writer based in Bellingham, WA. You can contact him via email at dcohn@az.com.

AutoCAD 2000

PRICE: $3750
(upgrades $495 from R14; $695 from R13; $995 from earlier versions available for a limited time only)

SYSTEM REQUIREMENTS:
Pentium compatible running at 133MHz or faster; Windows 95/98 or Windows NT 4.0; 32MB of RAM (64MB or more recommended); 150MB of disk space (64MB swap space); 1024x768 VGA display (800x600 minimum).

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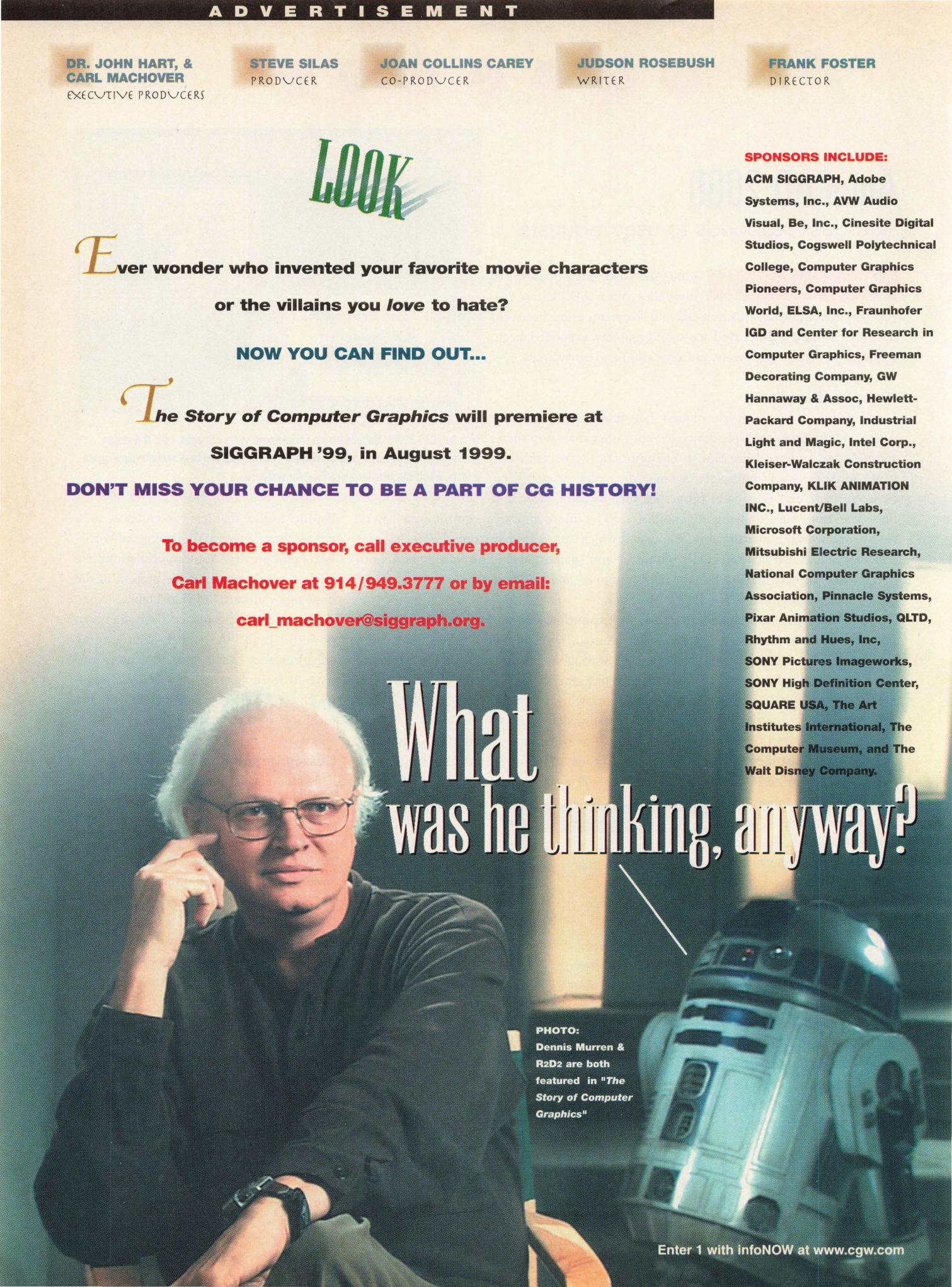

PHOTO: Dennis Murren & R2D2 are both featured in "*The Story of Computer Graphics*"

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Amorphium

Play's painterly approach to 3D modeling

BY ERIK HOLSINGER

Adding subtle embellishments to a 3D model is a difficult chore. Yes, you can add complexity in a texture map, but shine a bright light on your model and suddenly its perfect surfaces become glaringly obvious. Yet, most production schedules are so tight that they do not allow the time necessary to tweak 3D models for more realism.

One answer to this dilemma is Play Inc.'s Amorphium, a new 3D modeling tool for both Macintosh and Windows platforms that allows you to sculpt 3D surfaces with 2D paint tools, eliminating the slow and difficult wireframe editing associated with existing 3D systems. Although at $150, it's aimed at the consumer market, Amorphium is a surprisingly powerful modeling tool that should offer professional designers a new perspective on creating complex models.

Amorphium uses 2D tools to sculpt a 3D primitive into a shape, and includes tools to paint the model, as well.

For this review I looked at a pre-release version for the Mac. While it still has some shortcomings and bugs, I found it one of the most interesting 3D products to come out in a long time.

Face the Interface

Three-dimensional icons representing tools are arrayed on the right and left side of the interface. To start sculpting an image, pick a primitive, choose a brush, and go to it. As you apply the brush to the surface of a 3D shape, you create indentations (reversing the pressure adds more mass to the model). By using the 2D and 3D navigation tools, you can turn your model to any angle or position while sculpting its surface.

Amorphium's brushes range in shape from simple spikes to raised concentric circles, and all of them offer adjustable size, pressure, and flow. However, while the variety of brushes is a nice feature, different brushes sometimes yield similar results.

Also, while the interface is colorful, it needs more functionality. For example, you cannot change any of the brush controls on the fly using a mouse and key commands.

Another irksome feature is the small work area; currently you are limited to working in a 500x500-pixel window, which is too small for complex models.

Paint and Optics

Once you have finished sculpting your model, you can color it using Amorphium's 3D paint program, tilting and positioning your model as you paint colors onto each section. You can also adjust ambient, specular, and diffuse settings for each color, which is great when applying color to different parts of a model.

Amorphium sports an impressive undo feature. You can click on a button called "recording," which remembers every action you perform with the brush and saves the actions in a list. If you want to undo actions, you can back up.

Amorphium also gives you the ability to do basic metaball modeling, using its Biospheres function.

If all of these features weren't enough, Amorphium includes a morphing engine as well as a keyframe animation section that you can use to add life to your models. The engine does a good job of morphing between three separate 3D objects.

The keyframe animation section, called Composer, brings together different models in one space. You can adjust any number of models, change position, add a background image, and even add a fog/smoke filter to the image. While Composer is just a bare-bones keyframe animation tool, it is a nice touch.

Work in Progress

While I think Play has done a great job with this first version of Amorphium, it is clear that some hefty changes are due in the next release. I found a variety of bugs in the pre-release Mac version, from an inability to quit to the desktop to problems working with digitizer tablets. There is no doubt that the folks at Play were determined to pack as many features into Amorphium as possible, but I think they would have been better served if they added more functionality to fewer features. Yet, despite these concerns, I wouldn't hesitate to pick up the program. Where else can you find an organic 3D modeling/morphing/animation/metaball program for only $150?

Amorphium

PRICE: $149.95

SYSTEM REQUIREMENTS:
Mac OS 7.6.1 or later, Windows 98/NT 4.0, 32MB of RAM, 80MB of hard-disk space, 16-bit graphics card.

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SGI 320 Visual Workstation

One giant leap to NT

BY GEORGE MAESTRI

A few years ago, SGI ruled the 3D animation and graphics market with its Unix-based workstations. This dominance has been steadily eroded over the past few years by cheaper and faster machines running Microsoft Windows NT. SGI recently joined the fray with its own NT box, and has produced an excellent machine that is not only fast, but offers a number of promising new technologies and features.

The 320 is a single- or dual-processor Pentium II and Pentium III based system. SGI has also announced the 540, a Quad Xeon based system. All systems come with built-in 3D graphics acceleration, video in and out, and Firewire. Ethernet and USB are also included, and SCSI is available through an optional PCI card.

True to form, this SGI machine is unlike any other NT-based workstation. Instead of simply adding fancy graphics cards to a basic PC, SGI started from scratch with a machine aimed directly at graphics. It is built around SGI's Integrated Visual Computing (IVC) architecture, which consists of a fast (3.2 GB/sec) system bus that connects all the major subsystems, such as audio, video, and graphics acceleration—much like SGI's Unix-based Octane and O2 machines. This bus, however, is 50% faster than the Octane's, six times faster than AGP, and 12 times faster than the standard PCI bus. For those who need to use third-party cards, SGI provides two full-length PCI-64 slots, and one half-length PCI-32 slot.

The machine comes with NT already installed. Those used to having everything on their C: drive will need to get used to SGI's unique hard drive partitioning. The operating system is located on a small C: partition, with the CD-ROM at D:, another partition at E:, and the rest of the space at F: for data and applications. You need to be aware of this difference when installing software (which typically tries to install on the C: partition.)

Those who author 3D content will appreciate that 3D graphics acceleration is built into the motherboard. This means that the accelerator is connected to the processor and memory through the fast IVC bus, which eliminates the bottleneck of a PCI or AGP bus card. The accelerator itself uses SGI's Cobalt chipset, and is currently one of the fastest on the market. Considering that high-end OpenGL cards from third parties start at around $2,000, it gives the SGI machine a good bang for the buck. Perhaps one downfall is that the graphics cannot be upgraded without replacing the motherboard.

The 3D accelerator has no memory of its own—it simply shares system memory with the processor through the system bus. This gives you flexibility when deciding how much memory to dedicate to graphics acceleration and how much to applications. Once assigned, the memory is locked, so only the 3D accelerator can use it until the machine is rebooted. This means anywhere from 32 to 96MB of your system memory will be taken up for graphics, so you'll need to install that much more RAM in the system, which can be considered an extra expense. System RAM for the machine is non-standard and is installed through a 288-pin card available through SGI and third-party vendors such as Kingston. This custom memory promotes faster access, but it is about 25% more expensive than standard PC memory.

SGI 320 Visual Workstation

PRICE: $3395 for 350MHz Pentium II processor, 6GB IDE hard drive; $4705 for 450MHz Pentium II, 10GB hard drive

SGI Inc.

Mountain View, CA
650-960-1980; 888-400-4744.
www.sgi.com

infoNOW 96

The 320 Visual Workstation comes with SGI's flat-panel LCD monitor as an option.

When running real-world 3D programs such as 3D Studio Max, Mirai, Maya, and Softimage, the machine worked well. I've had compatibility problems on NT with some OpenGL based applications—but since SGI invented OpenGL, I wasn't surprised that I had no problems running the machine against this wide array of software.

One really nice feature of the system is its built-in video capability. The machine has two Firewire ports for digital video as well as s-video and composite connectors for analog video. With a fast SCSI disk, the 320 can handle two streams of NTSC video without breaking a sweat.

Overall, video quality was good, particularly with the Firewire ports. The one caveat is that SGI does not provide any software utilities to help capture video. Capture must be done through a third-party application, such as Premiere.

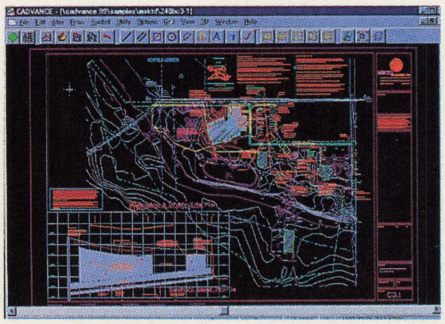
In sum total, the 320 Visual Workstation is a winner, a solid performer at a very attractive price. The OpenGL implementation is excellent, and the machine is one of the fastest 3D workstations on the market today.

George Maestri is the author of Character Animation.

SOFTWARE

ARCHITECTURAL DESIGN

DESIGN OPTIONS
WIN Cadvance 99 from Furukawa Information Technologies is a 32-bit architectural production tool that features 3D and complete integration of CAD with Windows. New features



include autosnap mode, multiple toolbars with ToolTips, right mouse button, key input command, and reference file-view window. The price is $1995. (Anaheim, CA; 714-956-3171; www.cadvance.com)
infoNOW 51

CAD TO ART
WIN New from Eagle Point Software, Virtual Image is a professional rendering package in which a drawing file can be rendered to a photo-realistic image. Users can paint on textures or symbols such as brick, stucco, wood, grass, and shrubbery with a single click. Plane-locking technology enables the user to render or color a discrete area of a model. After applying textures, users can add various effects such as watercolor, colored pencil, wet paint, charcoal, and edging to the rendering. The price was not available at press time. (Dubuque, IA; 319-556-8392; www.eaglepoint.com)
infoNOW 52

PLANT DESIGN
WIN/UNIX Create and visualize plant concepts in 3D using Design Power's PlantBuilder. The PlantDrafter module automatically produces fully annotated 2D drawings from 3D models created with PlantBuilder or PlantBuilder/AutoRouter software. Users can produce multiple drawing types, including plot plans, detached plans, piping, or isometric drawings. The company also offers complete drawing customization services. The price was not available at press time. (Cupertino, CA; 408-366-6600; www.dp.com)
infoNOW 53

DESIGN ENGINEERING

MECHANICAL ENGINEERING
WIN More than 450 enhancements are offered in IronCAD 2.0 from Visionary Design Systems. Sheet metal parts can be modeled by applying drag-and-drop techniques incorporating intelligent bend, lip, hem, and offset features. The handle technology provides behavior suited to the requirements of sheet metal design and modification. Using handle-based modifications, a user can perform precise sizing and positioning operations without regard to how

EVENTS

JUNE

14-16 · mecon[99]: the Congress for Digital Media Production, held in Germany. Contact: Musik Komm. GmbH (+49-221-91655-0); (fax: +49-221-91655-110); www.mecon.de

16-19 · Design Digital, 49th annual International Design Conferece, held in Aspen, CO. Contact: IDCA (970-925-2257); (fax: 970-925-8495); www.idca.org

20-23 · Pro/USER International Conference, held in Dallas. Contact: Pro/USER (500-PRO-USER or 814-451-8699); (fax: 781-925-2474); www.prouser.org

22-24 · PC EXPO, held in New York. Contact: Miller Freeman (800-950-1314 or 212-714-1300); (fax: 212-643-4802 or 5608); www.pcexpo.com

JULY

8-11 · The California Computer Expo and Conference, held in San Diego. Contact: The California Computer Expo (800-573-3247 or 619-573-0617); (fax: 619-573-0205); www.computoredge.com/expo

20-23 · MacWorld, held in New York. Contact: IDG (800-645-3976); www.macworldexpo.com

AUGUST

5-7 · The Big Picture Conference, held in Orlando, FL. Contact: ST Publications Inc. (800-925-1110 or 513-421-2050); (fax: 513-421-3076); www.bigpicture.net

8-13 · SIGGRAPH, held in Los Angeles. Contact: Smith, Bucklin & Assoc. Inc. (312-644-6610); (fax: 312-321-6878); www.siggraph.org/s99/

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	miroVIDEO DC30PRO	A/V Capture card w/Adobe Premiere 5.1 and Adobe	$850
	miroVIDEO DC50	A/V Capture card w/Adobe Premiere w/component I/O	$1750
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	DPS RT3DX	DPS Perception RT (RealTime)	$5999
	PVR 2500	Perception Video Capture Board NTSC only	$1579
FAST	AV Master Plus	PCI Video Capture with MediaStudio PRO 5	$599
	DV Master Pro	FireWire with speed razor DV Software	$2995

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	3Dfx 3000 AGP	Voodoo 3 16M 166Mhz SDRAM,Dual 32-bit,TV	$159
	3Dfx 2000	Voodoo 3 16M 143Mhz SDRAM,Dual 32-bit AGP/PCI	$115
STB Symmetric	Glyder GM238	Permedia II Chipset w/8M PCI	$79
	TX-GOLD 316	TX Chipset 8Mx8M PCI	$155
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	BlackMagic 3D	Voodoo2 3DFX Chipset with 12meg PCI	$128
	VELOCITY 128	nVIDIA Riva 128ZX AGP, TV Out	$85
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	AccelGMX 2000	Dual Gamma MX Chipset 16Mx80M, 2M VGA	$1450
	AccelEclipse II 32	Eclipse II Mitsubishi 3DPro/2mp32M AGP/PCI	$1080/$819
	AccelPRO 24MX	MX Chipset with 8Mx16M PCI/Accelstar II 8 AGP/PCI	$748/$135
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	GMX 2000	Dual Gamma MX Chipset 16Mx80M OpenGL AGP	$1450
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	GLoria Synergy 8	Permedia II Chipset 8M PCI / AGP Video in/out	$129/$129
	ERAZOR II / LT	16M nVIDIA RIVA TNT/8M RIVA 128ZX 2X AGP	$159/$99
matrox	Millenium	G-200 Comes with 8meg 2X AGP	$119
	Marvel G-200-TV	Comes with 8meg SGRAM and TV Tuner AGP	$265
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-Creative Labs Live Value PCI Sound Card w/ speakers & Subwoofer
-Toshiba SCSI 40X CDROM ,Iomega 100MB SCSI Internal Zip drive
-Microsoft Windows NT 4.0 Workstation with Service Pak 4
-Keytronic P/S2 Keyboard & Microsoft Intelli P/S2 Mouse
-Artmedia A-900T 19" 0.25AG 1600x1200 Sony Trinitron Tube Monitor
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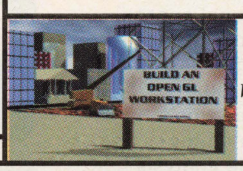

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the model was originally dimensioned. The product's SmartSnap functionality has been extended into 2D editing to provide an intelligent cursor, enabling dynamic, on-the-fly constraint feedback. Other new features include improved data translators and surface recognition algorithms. The price is $3995. (Santa Clara, CA; 408-969-8000; www.vds.com)
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MANIPULATING SURFACES

WIN Repair, conversion, and model processing of 3D CAD data is available with DeskArtes' 3Data Expert. Users can create accurately faceted STL models from IGES and VDA-FS files. The software also detects and automatically repairs various mistakes in the model. Other functionality includes positioning and scaling of models, splitting large models into parts, combining models with Boolean operations, offsetting models into solid sheets or hollow parts, and reducing the triangle count of STL models. The price was not available at press time. (Helsinki, Finland; +358-9-644 335; www.deskartes.com)
infoNOW 55

EXCHANGING IDEAS

WIN I-DEAS Web Access software from SDRC provides Web-based collaboration and visualization for organizations using I-DEAS software for mechanical design automation. Users can view parts, assemblies, and drawings with secure, native engineering data access via the Web. Three SDRC I-DEAS Solutions Network partners—CAD Centric Systems, RenderView Software, and Engineering Animation—offer visualization products enabled by I-DEAS Web Access. The price was not available at press time. (Millford, OH; 513-576-2400; www.sdrc.com)
infoNOW 56

OPTIMIZING DESIGNS

WIN iSIGHT Version 4.0 from Engineous Software offers improved usability, Design of Experiments (DOE) capabilities, additional approximation models, and tighter interfaces with Pro/Engineer and MSC/Nastran. A new GUI simplifies procedure setup, execution, and analyzing results. A visual program editor enables the user to couple analysis programs to iSIGHT. With DOE, users can explore a design space, prioritize design variables, and provide data for construction of approximation models. The approximation models accelerate the design process by reducing the number of full simulations required within a design search. The price was not available at price time. (Morrisville, NC; 919-319-7666; www.engineous.com)
infoNOW 57

ASSEMBLY BUILD ANALYSIS

WIN An assembly build analysis tool, Sigmund from Varatech enables design engineers to evaluate 3D process and assembly variations and their effects on the quality of products. Users can evaluate the assembly capability of their designs to ensure that assemblies go together 100% of the time, while meeting all assembly performance criteria. Engineers can build a large number of virtual assemblies for evaluation with respect to pre-defined build objectives. The software's animation capabilities provide visual feedback on assembly build violations, while providing direct access to a feature's deviated position at the violation. Sigmund is available as a standalone product and allows a direct API with Solidworks 98Plus. The price was not available at press time. (Holland, MI; 616-393-6408; www.varatech.com)
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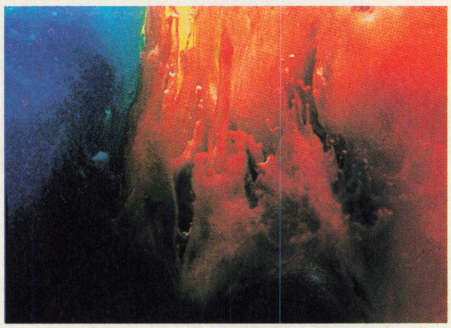
LIBRARIES

UNUSUAL ANIMATION

WIN/MAC Professional desktop editors and designers can use Liquid FX, Paint FX, and Text FX from TVFX Inc.



to add textures, backgrounds, and fills to their work. These full-motion, royalty-free titles feature water tank effects, nearly 50 edgy hand-painted textures, and high-energy looping graphic collages. The price is $350 each. (Needham, MA; 781-449-9296; www.tvfxinc.com)
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The products section is written by Contributing Editor Laureen Belleville.

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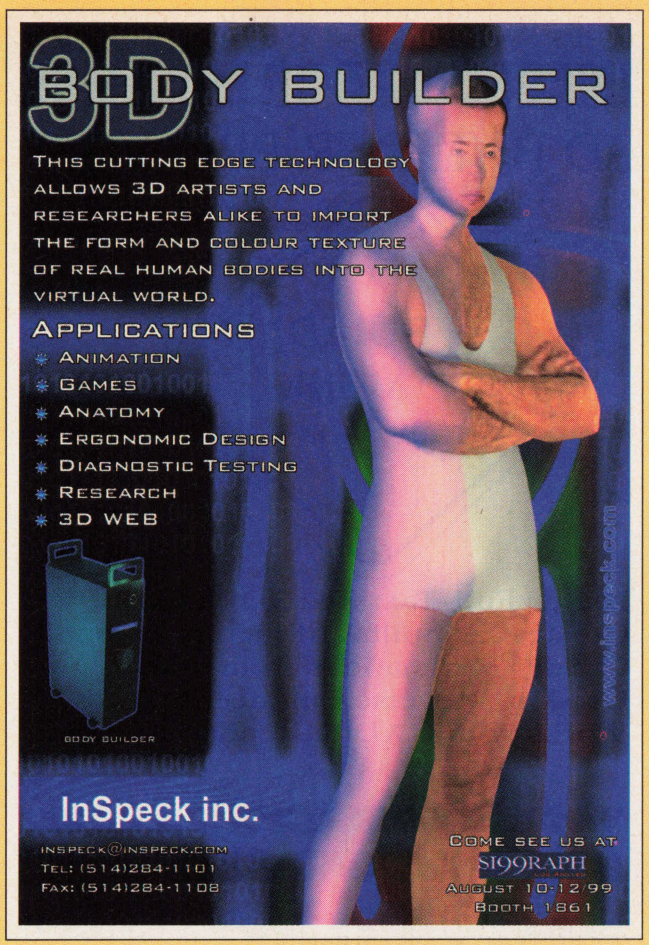

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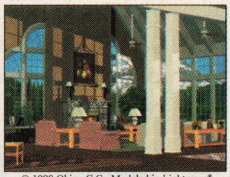
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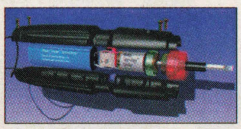
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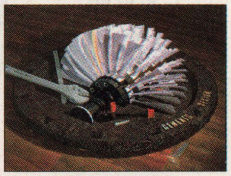
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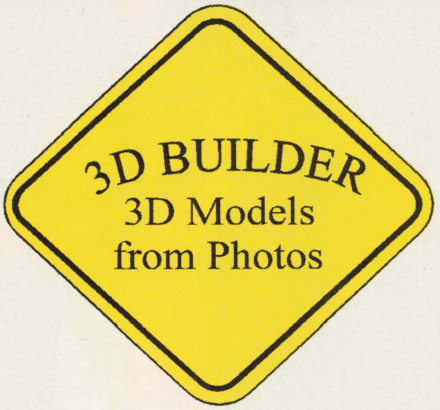

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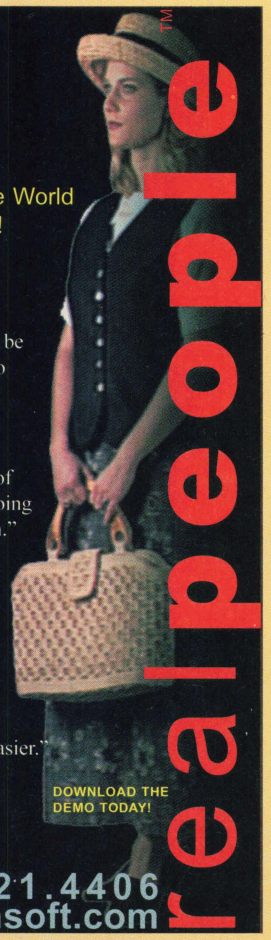

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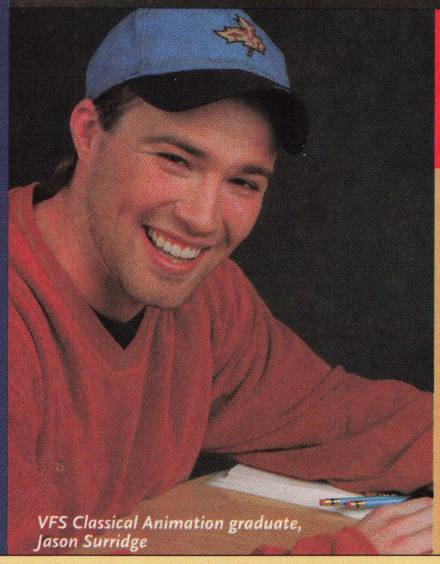

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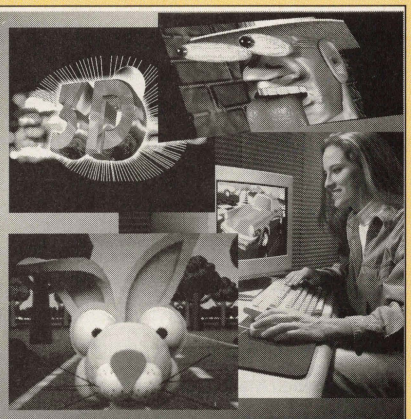

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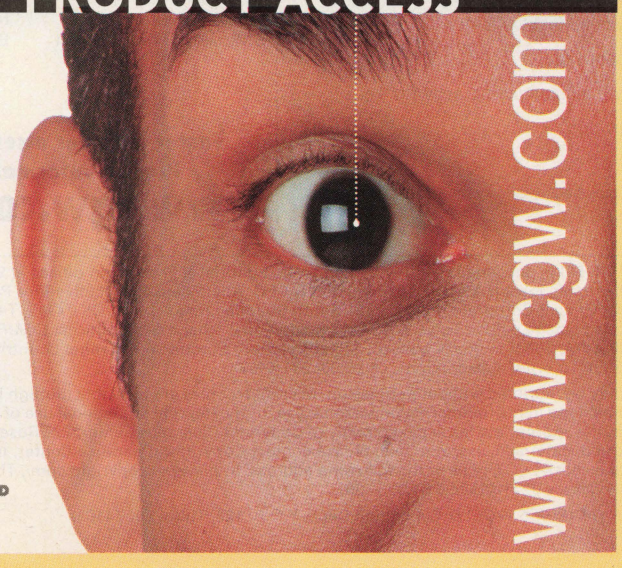

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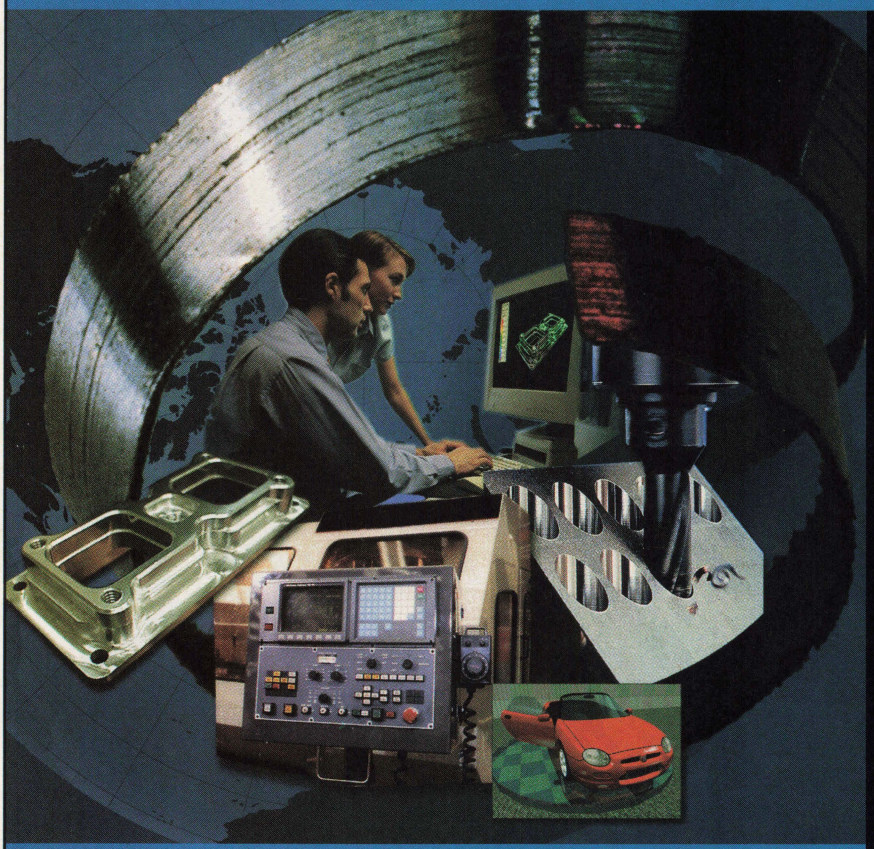

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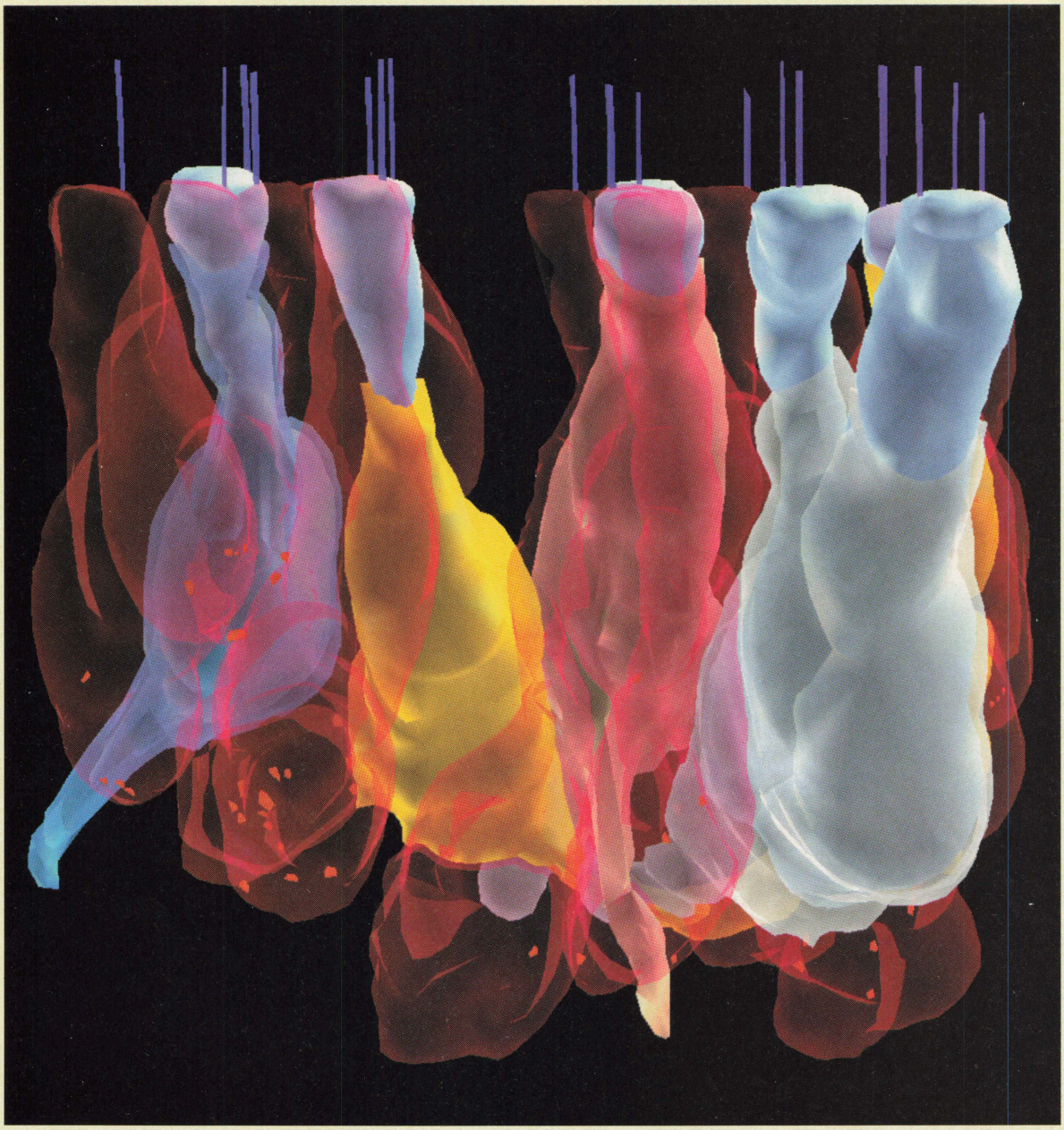

Why in the name of scientific inquiry are NASA researchers spending their time modeling drumsticks hanging on meathooks? The drumsticks are actually nerve endings (color coded in yellow, left center, and in semi-transparent gray, far right and left) in the portion of the inner ear devoted to sensing information for maintaining balance. Using electron microscopy data obtained during a space mission, researchers in the NASA Center for Bioinformatics at the NASA Ames Research Center (Moffet Field, CA) created the visualization with custom 3D reconstruction software to help scientists better understand the mammalian vestibular system, which is responsible for balance.

Here, the light blue and semi-transparent red structures represent two types of "sensing" hair cells. The lavender lines on top of the hair cells depict the direction of the stimulus to which the cells are most responsive. Through the visualization, researchers learned that the stimuli are actually oppositely tuned across the structure, rather than consistently tuned in the same direction, as had previously been believed. The orange dots represent the synapses, or regions of junction, in the red hair cells. The visualization was generated on a Silicon Graphics Indigo 2 workstation. —*Diana Phillips Mahoney*

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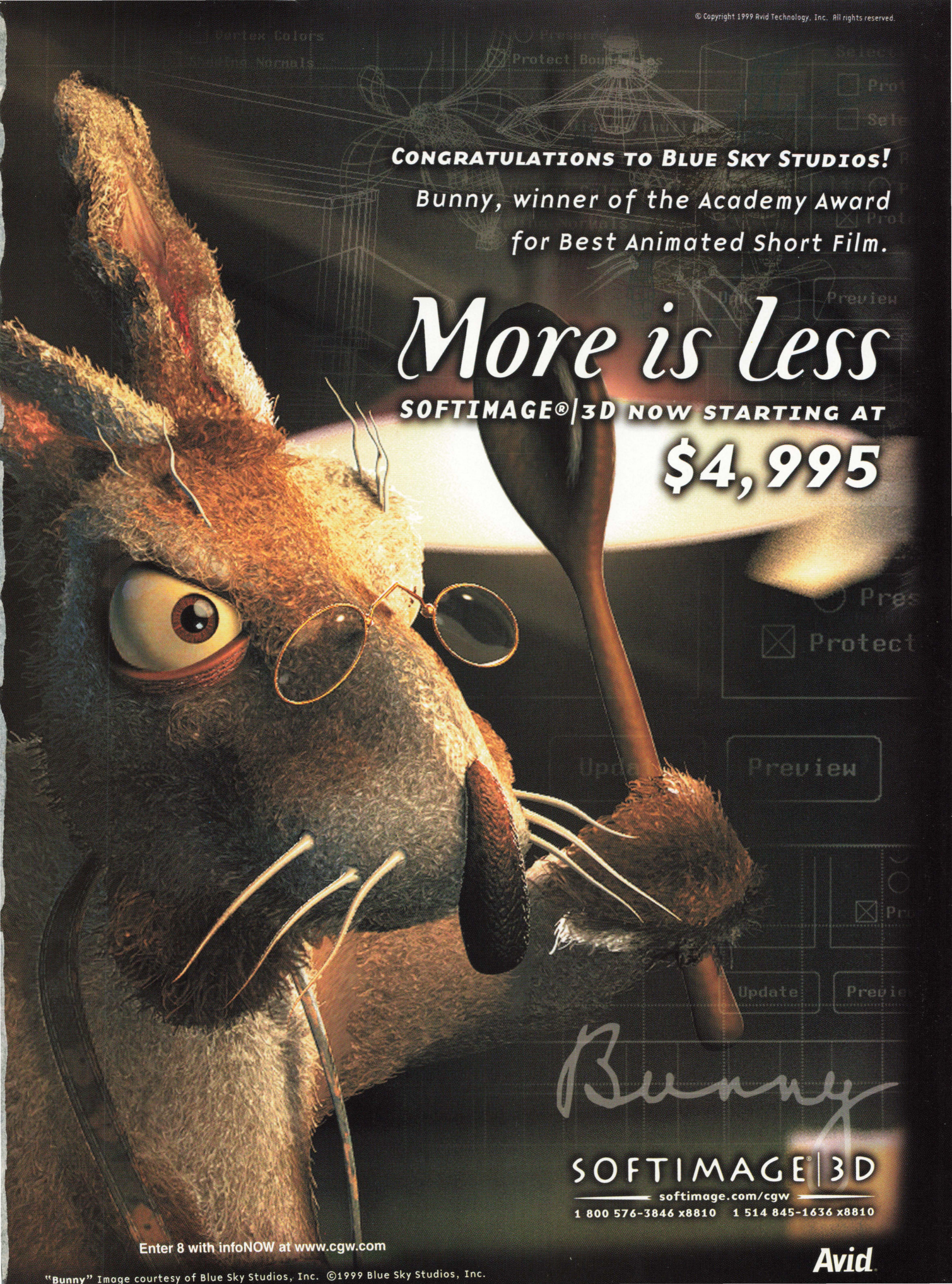

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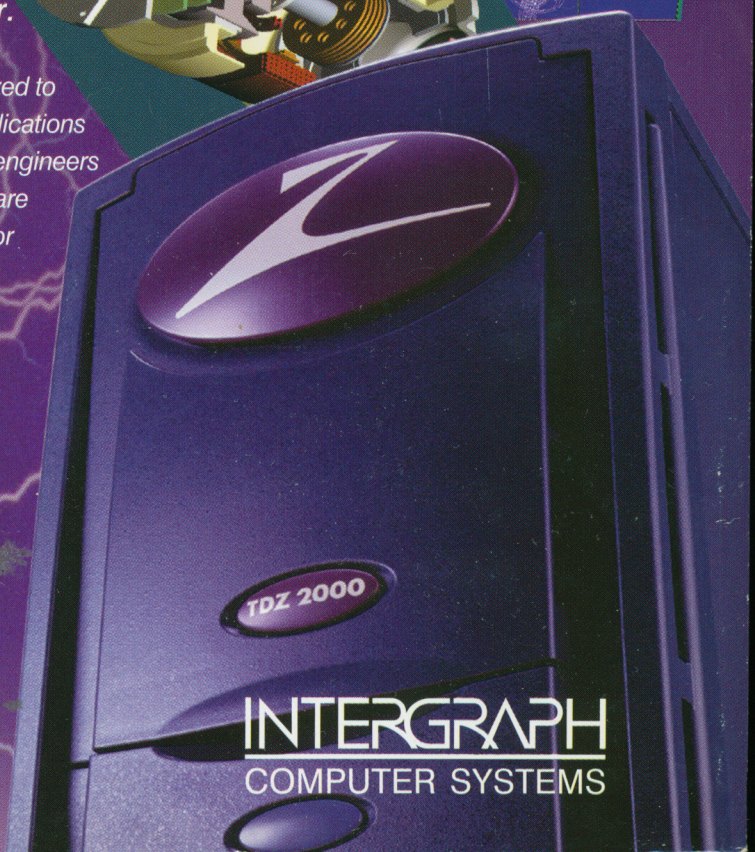

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